Table 12.1.--PMP Test Basin Comparison Summary

ID	BASIN NAME	STATE	AREA (SQ. MI)	ELEV (FT)	HMR RPT.	MONTH	STORM TYPE	CUMULATIVE PRECIPITATION (INCHES) FOR SELECTED OF DURATION (HOURS) 1	6	24	48	72
BUREAU OF RECLAMATION DAMS												
1	AGATE LAKE	OR	14	2210	57	DEC	GENERAL	1.11	4.46	11.20	16.69	19.82
						JUN	GENERAL	0.67	2.68	6.72	10.01	11.89
							LOCAL	5.66	6.76			
					43	DEC	GENERAL	1.73	4.64	11.12	15.65	18.47
						JUN	GENERAL	1.63	4.17	8.32	11.09	12.78
						JUN	LOCAL					
2	AGENCY VALLEY	OR	444	5200	57	DEC	GENERAL	1.15	4.00	7.98	10.64	11.99
						JUN	GENERAL	1.30	4.55	9.07	12.10	13.62
							LOCAL	1.79	2.24			
					43	DEC	GENERAL		3.24	7.31	10.07	11.52
						JUN	GENERAL		3.35	6.65	8.77	9.92
						AUG	LOCAL	1.85	4.18			
3	ANDERSON RANCH	ID	980	7103	57	DEC	GENERAL	1.41	4.92	9.98	13.24	15.23
						JUN	GENERAL	1.28	3.74	7.58	10.06	11.58
							LOCAL					
					43	DEC	GENERAL		3.39	9.14	13.57	15.76
						JUN	GENERAL		4.15	10.41	15.23	17.60
						JUN	LOCAL					
4	ARROWROCK	ID	1230	6933	57	DEC	GENERAL	1.34	4.76	9.68	13.03	14.81
						JUN	GENERAL	1.02	3.62	7.36	9.90	11.26
							LOCAL					
					43	DEC	GENERAL		3.28	8.76	12.92	14.99
						JUN	GENERAL		3.84	9.42	13.60	15.70
						JUN	LOCAL					
5	BOWMAN	OR	2635	4000	57	DEC	GENERAL	0.65	2.59	5.04	6.93	7.84
						JUN	GENERAL	0.67	2.67	5.19	7.14	8.00
							LOCAL					
					43	DEC	GENERAL		2.67	6.93	9.95	11.54
						JUN	GENERAL		2.40	5.70	7.95	9.16
						JUN	LOCAL					
6	BUMPING LAKE	WA	70	5467	57	DEC	GENERAL	3.25	10.86	21.22	28.86	33.23
						JUN	GENERAL	1.76	5.86	11.45	16.12	17.94
							LOCAL	3.80	4.53			
					43	DEC	GENERAL	1.64	5.53	15.63	23.47	27.47
						JUN	GENERAL	1.80	5.56	13.23	19.03	21.93
						AUG	LOCAL	4.29	7.91			
7	CASCADE	ID	620	5950	57	DEC	GENERAL	1.45	5.03	10.04	13.48	15.11
						JUN	GENERAL	1.23	4.27	8.54	11.46	12.84
							LOCAL					
					43	DEC	GENERAL		3.59	9.27	13.56	15.69
						JUN	GENERAL		4.28	10.12	14.45	16.63
						JUN	LOCAL					
8	COLD SPRINGS	OR	190	1320	57	DEC	GENERAL	0.91	3.03	5.26	6.47	7.06
						JUN	GENERAL	1.21	4.04	7.01	8.62	9.40
							LOCAL	3.07	3.72			
					43	DEC	GENERAL	1.30	3.62	7.47	9.85	11.13
						JUN	GENERAL	1.52	3.90	7.09	8.89	9.93
						AUG	LOCAL	2.96	6.08			

Table 12.1.--PMP Test Basin Comparison Summary (continued)

ID	BASIN NAME	STATE	AREA (SQ. MI)	ELEV (FT)	HMR RPT.	MONTH	STORM TYPE	CUMULATIVE PRECIPITATION (INCHES) FOR SELECTED OF DURATION (HOURS)				
								1	6	24	48	72
9	COMO	MT	55	6900	57	DEC	GENERAL	1.38	4.64	8.96	11.80	13.13
						JUN	GENERAL	1.92	6.44	12.45	16.39	18.24
							LOCAL	4.19	4.99			
					43	DEC	GENERAL	1.11	3.23	7.29	10.20	11.67
						JUN	GENERAL	1.85	4.96	9.55	12.61	14.20
						AUG	LOCAL	4.50	8.17			
10	CONCONULLY	WA	121	4489	57	DEC	GENERAL	1.26	4.29	8.33	11.79	13.06
						JUN	GENERAL	1.13	3.86	7.50	10.61	11.74
							LOCAL	3.05	3.63			
					43	DEC	GENERAL	1.25	4.00	10.53	15.34	17.89
						JUN	GENERAL	1.49	4.34	9.68	13.43	15.35
						AUG	LOCAL	3.34	6.72			
11	CRANE PRAIRIE	OR	163	5000	57	DEC	GENERAL	1.64	5.52	10.86	15.46	17.21
						JUN	GENERAL	1.10	3.70	7.28	10.36	11.54
							LOCAL	3.02	3.63			
					43	DEC	GENERAL	1.35	4.38	11.17	16.25	18.83
						JUN	GENERAL	1.24	3.65	8.23	11.45	13.12
						AUG	LOCAL	3.03	6.16			
12	DEADWOOD	ID	111	6770	57	DEC	GENERAL	1.88	6.41	12.39	16.32	18.15
						JUN	GENERAL	1.46	5.00	9.66	12.73	14.17
							LOCAL	4.02	4.82			
					43	DEC	GENERAL	1.27	4.04	9.79	14.09	16.24
						JUN	GENERAL	1.68	4.98	10.89	15.22	17.39
						AUG	LOCAL	3.59	6.94			
13	DEERFLAT	ID	92	2675	57	DEC	GENERAL	1.16	3.66	6.32	7.75	8.45
						JUN	GENERAL	1.18	3.75	6.47	7.94	8.65
							LOCAL	4.67	5.65			
					43	DEC	GENERAL	1.24	3.36	6.74	8.85	9.98
						JUN	GENERAL	1.55	3.95	6.95	8.68	9.65
						AUG	LOCAL	4.87	8.95			
14	DRY FALLS	WA	278	2325	57	DEC	GENERAL	0.82	2.81	4.91	6.08	6.67
						JUN	GENERAL	0.98	3.38	5.92	7.33	8.04
							LOCAL	2.18	2.66			
					43	DEC	GENERAL		3.14	6.86	9.25	10.58
						JUN	GENERAL		3.52	6.88	8.86	9.99
						AUG	LOCAL	2.26	4.93			
15	FISH LAKE	OR	19	6860	57	DEC	GENERAL	1.33	5.39	13.53	20.16	23.95
						JUN	GENERAL	0.84	3.40	8.53	12.71	16.09
							LOCAL	5.31	6.49			
					43	DEC	GENERAL	2.28	7.36	19.76	29.65	35.64
						JUN	GENERAL	1.94	5.82	13.94	20.27	24.15
						AUG	LOCAL	5.40	9.14			
16	FOURMILE LAKE	OR	11	6000	57	DEC	GENERAL	2.34	7.59	14.60	20.44	22.63
						JUN	GENERAL	1.47	4.78	9.20	12.88	14.26
							LOCAL	6.52	7.64			
					43	DEC	GENERAL	2.55	8.44	23.78	36.10	42.13
						JUN	GENERAL	2.15	6.51	16.60	24.51	28.40
						AUG	LOCAL	6.24	10.08			

Table 12.1.--PMP Test Basin Comparison Summary (continued)

ID	BASIN NAME	STATE	AREA (SQ. MI)	ELEV (FT)	HMR RPT.	MONTH	STORM TYPE	CUMULATIVE PRECIPITATION (INCHES) FOR SELECTED OF DURATION (HOURS) 1	6	24	48	72
17	HUNGRY HORSE	MT	1654	6303	57	DEC	GENERAL	1.01	3.57	7.07	9.45	10.68
						JUN	GENERAL	1.53	5.40	10.71	14.31	16.16
							LOCAL					
					43	DEC	GENERAL		2.55	6.83	10.05	11.67
						JUN	GENERAL		3.99	9.15	12.76	14.64
						JUN	LOCAL					
18	ISLAND PARK	ID	522	6250	57	DEC	GENERAL	1.33	4.51	8.78	11.44	12.72
						JUN	GENERAL	1.80	6.09	11.86	15.44	17.16
							LOCAL	1.12	1.44			
					43	DEC	GENERAL		2.93	7.61	11.18	12.95
						JUN	GENERAL		4.23	9.50	13.30	15.22
						JUN	LOCAL					
19	KACHESS	WA	64	3560	57	DEC	GENERAL	2.91	9.70	18.84	26.52	29.52
						JUN	GENERAL	1.45	4.65	9.43	13.27	14.76
							LOCAL	3.71	4.43			
					43	DEC	GENERAL	1.78	5.88	16.54	24.74	28.96
						JUN	GENERAL	1.92	5.81	14.06	20.22	23.28
						AUG	LOCAL	4.31	7.68			
20	LITTLE WOOD RIVER	ID	275	6740	57	DEC	GENERAL	1.69	5.78	11.37	15.24	17.06
						JUN	GENERAL	1.49	5.08	10.01	13.41	15.01
							LOCAL	2.50	3.03			
					43	DEC	GENERAL		4.20	11.06	16.40	19.02
						JUN	GENERAL		5.24	12.48	17.98	20.70
						AUG	LOCAL	2.49	5.28			
21	MASON	OR	165	5233	57	DEC	GENERAL	1.37	4.66	9.22	12.14	13.52
						JUN	GENERAL	1.60	5.42	10.72	14.12	15.72
							LOCAL	3.51	4.20			
					43	DEC	GENERAL	1.50	4.83	11.78	16.96	19.58
						JUN	GENERAL	1.89	5.90	13.91	19.99	23.01
						AUG	LOCAL	3.24	6.60			
22	McKAY	OR	186	3006	57	DEC	GENERAL	1.22	4.10	8.16	11.49	12.79
						JUN	GENERAL	1.55	5.26	10.47	14.73	16.40
							LOCAL	3.19	3.83			
					43	DEC	GENERAL	1.35	3.97	8.62	11.75	13.41
						JUN	GENERAL	1.57	4.25	8.11	10.56	11.88
						AUG	LOCAL	2.96	6.20			
23	OCHOCO	OR	295	4925	57	DEC	GENERAL	1.09	3.73	7.39	10.40	11.58
						JUN	GENERAL	1.12	3.84	7.61	10.72	11.94
							LOCAL	2.31	2.85			
					43	DEC	GENERAL		4.14	10.30	14.85	17.16
						JUN	GENERAL		3.79	8.64	12.13	13.92
						AUG	LOCAL	2.24	5.03			
24	O'SULLIVAN	WA	3920	1752	57	DEC	GENERAL	0.35	1.53	2.91	3.77	4.24
						JUN	GENERAL	0.47	2.04	3.88	5.03	5.65
							LOCAL					
					43	DEC	GENERAL		2.24	5.79	8.13	9.45
						JUN	GENERAL		2.39	5.39	7.23	8.28
						JUN	LOCAL					

Table 12.1.--PMP Test Basin Comparison Summary (continued)

ID	BASIN NAME	STATE	AREA (SQ. MI)	ELEV (FT)	HMR RPT.	MONTH	STORM TYPE	CUMULATIVE PRECIPITATION (INCHES) FOR SELECTED OF DURATION (HOURS) 1	6	24	48	72
25	OWYHEE	OR	10900	5000	57	DEC	GENERAL	0.41	1.69	3.70	5.21	6.15
						JUN	GENERAL	0.36	1.51	3.29	4.64	5.47
							LOCAL					
					43	DEC	GENERAL		1.57	4.40	6.36	7.40
						JUN	GENERAL		1.54	3.84	5.35	6.18
						JUN	LOCAL					
26	PALISADES	ID	5150	8000	57	DEC	GENERAL	0.63	2.31	4.81	6.55	7.59
						JUN	GENERAL	0.68	2.54	5.29	7.20	8.34
							LOCAL					
					43	DEC	GENERAL		1.83	5.22	7.79	9.08
						JUN	GENERAL		2.42	6.11	8.76	10.12
						JUN	LOCAL					
27	RIRIE	ID	797	6300	57	DEC	GENERAL	0.81	2.83	5.73	7.65	8.72
						JUN	GENERAL	0.87	3.03	6.15	8.20	9.37
							LOCAL					
					43	DEC	GENERAL		2.48	6.18	8.88	10.24
						JUN	GENERAL		3.53	7.58	10.35	11.79
						JUN	LOCAL					
28	SCOGGINS	OR	39	1950	57	DEC	GENERAL	1.99	7.61	18.68	26.18	30.52
						JUN	GENERAL	1.32	5.02	12.33	17.29	20.15
							LOCAL	3.47	4.10			
					43	DEC	GENERAL	1.59	4.32	11.13	15.80	18.65
						JUN	GENERAL	1.63	4.15	8.31	10.96	12.55
						JUN	LOCAL					
29	THEIF VALLEY	OR	910	6066	57	DEC	GENERAL	0.98	3.56	7.25	9.72	10.95
						JUN	GENERAL	1.14	4.14	8.43	11.30	12.72
							LOCAL					
					43	DEC	GENERAL		3.57	8.82	12.61	14.56
						JUN	GENERAL		4.00	9.11	12.74	14.62
						JUN	LOCAL					
30	UNITY	OR	309	4820	57	DEC	GENERAL	1.18	4.08	8.07	10.64	11.84
						JUN	GENERAL	1.37	4.69	9.28	12.23	13.61
							LOCAL	2.39	2.95			
					43	DEC	GENERAL		3.81	8.81	12.34	14.17
						JUN	GENERAL		3.99	8.13	10.90	12.36
						AUG	LOCAL	2.24	5.04			
31	WASCO	OR	9	3750	57	DEC	GENERAL	3.07	9.87	19.17	26.84	29.71
						JUN	GENERAL	1.99	6.48	12.46	17.44	19.31
							LOCAL	6.23	7.27			
					43	DEC	GENERAL	2.21	6.80	18.97	28.50	33.30
						JUN	GENERAL	2.24	6.41	15.67	23.14	26.71
						AUG	LOCAL	6.48	10.27			
32	WICKIUP	OR	97	4800	57	DEC	GENERAL	1.58	5.38	10.44	14.69	16.36
						JUN	GENERAL	1.10	3.77	7.31	10.29	11.46
							LOCAL	3.98	4.76			
					43	DEC	GENERAL	1.38	4.23	10.34	14.80	17.08
						JUN	GENERAL	1.34	3.84	8.53	11.84	13.56
						AUG	LOCAL	3.94	7.42			

Table 12.1.--PMP Test Basin Comparison Summary (continued)

ID	BASIN NAME	STATE	AREA (SQ. MI)	ELEV (FT)	HMR RPT.	MONTH	STORM TYPE	CUMULATIVE PRECIPITATION (INCHES) FOR SELECTED OF DURATION (HOURS) 1	6	24	48	72
CORPS OF ENGINEERS DAMS												
33	APPLEGATE	OR	223	4210	57	DEC	GENERAL	1.39	5.76	14.92	22.48	27.00
						JUN	GENERAL	0.93	3.86	9.99	15.06	18.09
							LOCAL	2.28	2.80			
					43	DEC	GENERAL		5.22	14.38	21.52	25.91
						JUN	GENERAL		4.05	9.91	14.38	17.12
						JUN	LOCAL					
34	BLUE RIVER	OR	88	3050	57	DEC	GENERAL	1.86	7.69	19.43	29.26	34.94
						JUN	GENERAL	0.84	3.46	8.73	13.15	15.70
							LOCAL	3.72	4.49			
					43	DEC	GENERAL	2.11	7.32	20.73	31.35	37.87
						JUN	GENERAL	1.90	5.96	14.71	21.49	25.59
						JUN	LOCAL					
35	CEDAR RIVER	WA	81	3230	57	DEC	GENERAL	1.83	7.58	19.15	28.69	34.25
						JUN	GENERAL	1.06	4.40	11.11	16.63	19.86
							LOCAL	3.37	4.01			
					43	DEC	GENERAL	2.18	7.65	23.56	36.17	43.84
						JUN	GENERAL	2.13	6.71	16.94	24.93	29.75
						JUN	LOCAL					
36	CRAB CREEK	WA	1765	2150	57	DEC	GENERAL	0.52	2.08	3.79	4.73	5.27
						JUN	GENERAL	0.66	2.63	4.80	5.99	6.68
							LOCAL					
					43	DEC	GENERAL		2.77	6.67	9.25	10.66
						JUN	GENERAL		3.05	6.61	8.84	10.09
						JUN	LOCAL					
37	DETROIT DAM	OR	438	3718	57	DEC	GENERAL	1.57	6.59	17.09	26.08	31.34
						JUN	GENERAL	0.86	3.63	9.40	14.34	17.23
							LOCAL	1.47	1.86			
					43	DEC	GENERAL		6.38	19.10	29.24	34.34
						JUN	GENERAL		4.98	13.30	19.74	22.91
						JUL	LOCAL	1.72	3.81			
38	GATE CREEK	OR	46	2230	57	DEC	GENERAL	1.69	6.91	17.46	26.02	30.90
						JUN	GENERAL	0.77	3.15	7.95	11.85	14.07
							LOCAL	4.28	5.11			
					43	DEC	GENERAL	2.36	8.17	23.36	35.60	43.08
						JUN	GENERAL	2.10	6.58	16.53	24.34	29.06
						JUN	LOCAL					
39	GREEN RIVER	WA	221	3100	57	DEC	GENERAL	1.57	6.49	16.79	25.30	30.39
						JUN	GENERAL	0.85	3.51	9.07	13.66	16.42
							LOCAL	2.22	2.69			
					43	DEC	GENERAL		6.31	18.87	28.85	34.95
						JUN	GENERAL		5.38	13.53	19.80	23.59
						JUN	LOCAL					
40	HILLS CREEK DAM	OR	389	3920	57	DEC	GENERAL	1.30	5.52	14.30	21.55	25.90
						JUN	GENERAL	0.65	2.76	7.15	10.78	12.95
							LOCAL	1.64	2.06			
					43	DEC	GENERAL		6.07	17.98	27.42	32.17
						JUN	GENERAL		4.72	12.46	18.46	21.42
						JUL	LOCAL	1.92	4.14			

Table 12.1.--PMP Test Basin Comparison Summary (continued)

ID	BASIN NAME	STATE	AREA (SQ. MI)	ELEV (FT)	HMR RPT.	MONTH	STORM TYPE	CUMULATIVE PRECIPITATION (INCHES) FOR SELECTED OF DURATION (HOURS) 1	6	24	48	72
41	HOLLEY RESERVOIR	OR	105	2040	57	DEC	GENERAL	1.64	6.76	17.28	26.02	31.07
						JUN	GENERAL	0.77	3.18	8.12	12.23	14.60
							LOCAL	3.25	3.86			
					43	DEC	GENERAL	1.86	6.07	16.76	24.98	30.03
						JUN	GENERAL	1.74	5.14	12.04	17.14	20.21
						JUN	LOCAL					
42	PLACER CREEK	ID	15	4380	57	DEC	GENERAL	1.83	6.02	11.64	15.33	16.97
						JUN	GENERAL	1.58	5.18	10.01	13.18	14.59
							LOCAL	5.76	6.64			
					43	DEC	GENERAL	1.72	4.40	9.35	12.71	14.45
						JUN	GENERAL	2.68	6.71	12.19	15.67	17.51
						JUL	LOCAL	6.00	9.98			
43	SKOOKUMCHUCK	WA	62	1700	57	DEC	GENERAL	1.44	5.92	14.97	22.53	26.76
						JUN	GENERAL	0.87	3.61	9.13	13.74	16.33
							LOCAL	3.08	3.66			
					43	DEC	GENERAL	1.77	5.43	15.08	22.23	26.60
						JUN	GENERAL	1.78	4.92	10.97	15.27	17.85
						JUN	LOCAL	4.26	7.81			
44	SOLEDUCK	WA	84	2900	57	DEC	GENERAL	2.08	8.60	21.73	32.73	39.28
						JUN	GENERAL	1.22	5.08	12.82	19.30	23.17
							LOCAL	1.83	2.20			
					43	DEC	GENERAL	1.98	7.33	22.63	35.00	42.55
						JUN	GENERAL	1.67	5.61	15.04	22.67	27.30
						JUN	LOCAL					
45	WHITE RIVER	WA	402	3750	57	DEC	GENERAL	1.39	5.85	15.15	22.83	27.44
						JUN	GENERAL	0.78	3.27	8.48	12.79	15.36
							LOCAL	1.40	1.76			
					43	DEC	GENERAL		6.11	18.64	28.81	35.02
						JUN	GENERAL		5.00	13.23	19.70	23.61
						JUN	LOCAL					
46	WILLOW CREEK	OR	96	3500	57	DEC	GENERAL	1.05	3.52	6.92	9.79	10.95
						JUN	GENERAL	1.40	4.69	9.22	13.04	14.60
							LOCAL	4.18	4.99			
					43	DEC	GENERAL	1.47	4.11	8.75	11.81	13.40
						JUN	GENERAL	1.61	4.24	7.99	10.30	11.57
						AUG	LOCAL	3.79	7.41			
47	WYNOOCHEE RIVER	WA	40	2000	57	DEC	GENERAL	3.33	13.48	34.04	50.71	60.25
						JUN	GENERAL	1.97	7.95	20.08	29.91	35.54
							LOCAL	2.47	2.92			
					43	DEC	GENERAL	2.72	9.72	29.39	45.25	54.90
						JUN	GENERAL	2.35	7.61	19.90	29.77	35.75

Table 12.2.--Percent Change in Individual Drainage PMP (Present Study vs. HMR 43)

Month		Percent Change[*] in Individual Drainage PMP (Present Study vs HMR 43) Duration (hrs)				
		1	6	24	48	72
June	Range	-63 to 4	-52 to 44	-52 to 48	-51 to 58	-52 to 61
	Mean	-28	-7	-13	-13	-14
December	Range	-42 to 98	-32 to 96	-50 to 68	-54 to 66	-55 to 63
	Mean	4	16	-5	-9	-11

[*] Negative percentages indicate that PMP computed from the present study is less than that obtained from HMR 43.

13. COMPARISON STUDY

The comparisons used to assess the level of PMP estimates derived in this study emulate similar evaluations made for previous studies. These comparisons provide a means for determining the range of acceptability of the final results. As in other studies, comparisons most often made are between the PMP estimates and 1) 100-year precipitation frequency amounts, 2) previous studies, 3) observed storm maxima, and 4) those for neighboring regions. Such comparisons for the Northwest are discussed in this chapter.

13.1 Comparison to NOAA Atlas 2

General storm PMP for 1, 6, and 24 hours were compared to 100-year precipitation frequency analyses from NOAA Atlas 2 for the same durations. At 72 hours, comparisons were made using a technique developed by Styner (1975). Table 13.1 presents a summary of some of the findings from this comparison and is separated west and east of 117°W longitude (this separation was made for ease in use of the oversize PMP index maps).

Table 13.1 contains two sets of comparison data: (a) the range of ratios of PMP/100-year rainfall over U. S. portions of the eastern and western PMP index maps for four durations (1, 6, 24, and 72-hours); and (b) similar ratios for ten selected locations. PMP, by definition, is larger than 100-year amounts for comparable storm types and therefore the ratios should be larger than one with few exceptions. However, the comparison is less clear when it is realized that the 100-year precipitation data comes from a composite of storm types. It is also likely that the short-duration (1-3 hours) 100-year data represents short-duration convective events, while the 24- and 72-hour data may be from general-type storms. Since storm type is not known for the NOAA Atlas 2 data, these comparisons can be misleading if improperly applied. Nevertheless, this study has accepted the 100-year data as the best precipitation frequency information available and used it extensively throughout as a basis for PMP development.

As for maximum ratios, the values of 3.2 to 7.5 shown in Table 13.1 are also found in similar comparisons from other PMP studies (Hansen et al. 1977; Hansen et al. 1988; Riedel and Schreiner, 1980). It is generally found that ratios increase with distance from the moisture source, and as the durations increase. It has also been observed that these ratios tend to increase in those regions where the frequency of large rains decreases; i.e., where the potential for PMP exists, but where, historically, rains have not been large (Riedel and Schreiner, 1980).

With this insight in mind, the results in Table 13.1 a and b were reviewed. The 1-hour PMP/100-year ratio maps (both east and west) show only one region in which the ratios are less than one, and that it is at the northeastern tip of the Olympic Peninsula. However, if the 1-hour local storm PMP are compared to 1-hour, 100-year values in these regions, ratios of 3.0 or better are obtained everywhere (see also Table 13.2).

Table 13.1.--Comparison between HMR 57 general storm PMP estimates and 100-year precipitation frequency data from NOAA Atlas 2 for subregional analysis and selected individual locations (10-mi²).

Range of PMP/100-year Ratios

a.

	West of 117°W				East of 117°W			
	Duration (hours)				Duration (hours)			
	1	6	24	72	1	6	24	72
Minimum	0.9	1.8	2.2	2.2	1.2	2.2	2.6	2.5
Maximum	3.2	3.9	4.8	5.0	3.3	6.5	5.5	7.5

b.

West of 117°W

	(Lat.)	(Long.)	1	6	24	72
1.	48.2	123.0	0.9	1.9	2.8	3.6
2.	47.5	123.5	2.4	2.6	2.6	2.6
3.	45.4	123.0	1.6	2.6	2.8	3.0
4.	44.6	121.8	2.0	3.8	2.8	2.6
5.	47.2	119.4	1.4	3.1	4.2	4.5
6.	45.9	118.0	2.0	3.3	3.4	5.0

East of 117°W

	(Lat.)	(Long.)	1	6	24	72
7.	43.0	113.0	1.6	3.1	4.2	4.2
8.	47.5	114.5	1.4	2.6	3.4	3.4
9.	46.3	114.4	1.6	2.8	3.0	3.0
10.	44.5	113.0	3.2	5.6	5.1	5.5

Locations

1. San Juan Island, Washington
2. Olympics Mountains, Washington
3. Willamette Valley, Oregon
4. Cascade Mountains, Oregon
5. Columbia River Plateau, Washington
6. Blue Mountains, Oregon
7. Snake River Valley, Idaho
8. Flathead River Valley, Montana
9. Bitterroot Mountains, Idaho
10. Bitterroot Mountains, Montana (Continental Divide)

Table 13.1b shows that for durations 6 hours or longer, PMP to 100-year ratios are generally between 2 and 5.5 at the locations considered. This range is clearly acceptable. With the exception of the site along the Continental Divide, the ratios show no appreciable distinction between mountain and valley locations. The largest ratios occur near and along the Continental Divide. This is the result of relatively low 100-year amounts along this boundary, while the PMP estimates both in this study and in HMR 55A are relatively high.

Table 13.2 shows comparisons between the present study (HMR 57) and NOAA Atlas 2 values for local storms at 1 hour for the same 10 locations considered in Table 13.1. Ratios of PMP to 100-year values shown in column c. of Table 13.2 indicate that local storm PMP is everywhere more than double NOAA Atlas 2 precipitation values.

Table 13.2.--Comparison between HMR 57 local-storm PMP and NOAA Atlas 2 amounts for 1-hour, 10-mi^2 for locations in Table 10.1.

Location (Lat., Long.)	a. 1-hour PMP	b. 1-hour, 100-year	c. Ratio a/b
1. 48.2, 123.0	2.97	0.96	3.09
2. 47.5, 123.5	3.14	1.35	2.33
3. 45.4, 123.0	4.58	0.93	4.92
4. 44.6, 121.8	6.15	1.03	5.97
5. 47.2, 119.4	6.35	0.99	6.41
6. 45.9, 118.0	6.89	1.15	5.99
7. 43.0, 113.0	7.67	1.06	7.24
8. 47.5, 114.5	6.06	0.64	9.47
9. 46.3, 114.4	6.39	1.25	5.11
10. 44.5, 113.0	6.52	0.76	8.58

13.2 Comparison to HMR 43

PMP estimates from this study were also compared against PMP estimates derived from HMR 43. Since the results of HMR 43 are not readily available as a map analysis, data were available only for a 1/4° latitude-longitude grid that had been developed in the late 1960's to verify HMR 43 results. Considerably less detail was provided in this comparison in contrast to the PMP/100-year comparisons.

Table 13.3 gives results of this comparison for general storms in the same format and for the same locations as was given for Table 13.1, and therefore allows for some internal comparisons between the two sets of comparisons.

No 1-hour general storm values were available in the catalog of 1/4° grid data computed for HMR 43. Although the procedure to obtain 1-hour PMP estimates is given in HMR 43, past experience had shown that in many locations, results were exceeded by 100-year values. In fact, one of the reasons for initiating this revised study was to reevaluate the 1-hour PMP.

From Table 13.3, it is evident that at a number of locations (three of ten), the new general storm PMP estimates are lower than those obtained from HMR 43. During the planning for this study, it was stated that the revised estimates could

Table 13.3.--Comparison between HMR 57 general storm PMP estimates and HMR 43 PMP estimates for subregional analysis and selected individual locations (10-mi^2).

Range of PMP (57)/PMP (43) Ratios

a.

West of 117°W	Duration (hours) 6	24	72	East of 117°W	Duration (hours) 6	24	72
Minimum	0.7	0.6	0.6	Minimum	0.7	0.8	0.6
Maximum	1.9	1.7	1.8	Maximum	2.4	2.2	1.8

b.

West of 117°W	(Lat.)	(Long.)	Duration (hours) 6	24	72
1.	48.2	123.0#	0.9	0.8	0.6
2.	47.5	123.5	1.3	1.1	1.1
3.	45.4	123.0#	1.2	1.3	1.0
4.	44.6	121.8#	1.3	1.1	1.0
5.	47.2	119.4#	0.9	0.9	0.8
6.	45.9	119.0#	1.2	1.2	0.9

East of 117°W	(Lat.)	(Long.)	Duration (hours) 6	24	72
7.	43.0	113.0	1.1	1.1	1.0
8.	47.5	114.5	0.8	0.9	0.9
9.	46.3	114.4#	1.2	1.3	1.1
10.	44.5	113.0	1.2	2.0	1.4

Computed at nearest 1/4° grid point

Locations

1. San Juan Island, Washington
2. Olympics Mountains, Washington
3. Willamette Valley, Oregon
4. Cascade Mountains, Oregon
5. Columbia River Plateau, Washington
6. Blue Mountains, Oregon
7. Snake River Valley, Idaho
8. Flathead River Valley, Montana
9. Bitterroot Mountains, Idaho
10. Bitterroot Mountains, Montana (Continental Divide)

be both higher and/or lower than HMR 43, as it was not known at that time how the results of the storm data analysis would compare to the orographic model procedure used in HMR 43. Now that this study is completed, the comparisons made here show that the new estimates are slightly higher in the mountains but lower than HMR 43 by considerable amounts elsewhere.

This conclusion might bring about concern that the new general storm values may be too low, were it not for two facts. The first is that while general storm PMP has been reduced in some locations, comparisons against NOAA Atlas 2 amounts (Table 13.1) indicate a reasonable ratio (values greater than 1.5) of PMP/100-years still prevails for all durations except less than 6 hours. The second is that the local-storm PMP to 100-year comparisons show everywhere that substantial ratios exist for shorter durations as well, as shown in Table 13.2.

13.3 Comparisons Between General and Local-Storm PMP

The comparisons discussed in Section 13.1 suggest that the local-storm PMP is everywhere larger than the general-storm PMP at the shorter durations. The information in Table 13.4 shows comparisons between general- and local-storm PMP for this study at 1 and 6 hours for the 10 specified sites used previously (see Table 13.1). In Table 13.4 for 1 hour, only the location at the top of the Olympic Mountains shows a ratio greater than one. At 6 hours (although the value from the Continental Divide comes close), most locations show a ratio greater than one. While the comparison involves all-season general-storm PMP, it can be assumed the local-storm PMP applies primarily to the summer months. One can see from Figures 9.4 to 9.10 that summer general-storm values are fractions of the all-season amounts, so that the ratios shown for the first four sites in Table 13.4 would be somewhat lower had the comparison been made for June, for example.

Table 13.4.--Comparison between general- and local-storm PMP in this study (10-mi^2).

Location	(Lat.	Long.)	a. 1-hour general storm PMP	b. 1-hour local storm PMP	Ratio a/b	c. 6-hour general storm PMP	d. 6-hour local storm PMP	Ratio c/d
1.	48.2,	123.0	0.90	2.97	0.30	3.30	3.42	0.96
2.	47.5,	123.5	3.60	3.14	1.15	14.40	3.61	3.99
3.	45.4,	123.0	1.52	4.58	0.33	5.59	5.27	1.06
4.	44.6,	121.8	2.59	6.15	0.42	10.36	7.07	1.47
5.	47.2,	119.4	1.56	6.35	0.25	4.60	7.30	0.63
6.	45.9,	118.0	2.46	6.89	0.36	8.01	7.92	1.01
7.	43.0,	113.0	1.68	7.67	0.22	4.96	8.82	0.56
8.	47.5,	114.5	1.55	6.06	0.26	5.04	6.97	0.72
9.	46.3,	114.4	2.13	6.39	0.33	6.92	7.35	0.94
10.	44.5,	113.0	3.96	6.52	0.61	12.10	7.50	1.61

13.4 Comparisons to Observed Storm Maxima

Observed major storms listed in Table 2.1 have been compared to the general-storm PMP derived in this study in Table 13.5. Ratios of PMP to observed amounts and PMP to in-place moisture maximized amounts are given in columns a and b, respectively. Selected durations and areas were chosen at which to make the comparisons in this table. PMP for storms 59, 82 and 126 have been adjusted by the seasonal percentages in Figures 9.4 to 9.10. Storms 29 and 155 take their PMP from HMR 55A, and storms 156 and 165 are in California beyond the reach of the analyzed index maps. Similarly, the two Canadian storms in Table 2.1 are outside the region of this analysis. A number of interesting results are apparent. Some of these are:

1. The general uniformity of ratios across the selected durations and areas. It does not appear that PMP envelops moisture maximized observed storm amounts by any greater or lesser degree as one varies duration and/or area. This implies that the depth-area-duration relations adopted in this study are reasonable representations of storm behavior.

2. Ratios of PMP to observed storm amounts shown in column a are generally larger than 2.0. Storm 126 (at 1 and 24 hours, 10-mi^2) and storms 38 and 80 (at 1-hour, 10-mi^2) have ratios between 1 and 2. A ratio between 1 and 2 also occurs for storm 106 (at 24 hours, 1000-mi^2). It should be noted that while most of the ratios of PMP to observed amounts are over 2, this is not necessarily typical of ratios for these storms at durations and areas not given in this table. It can be stated that PMP everywhere exceeds the observed storm amounts for all durations and areas.

3. Storms 80 and 126 are the most significant storms in the sample relative to their moisture maximized values. They exert the greatest control over the level of PMP in this study. In Table 13.5 (Column b), the moisture maximized storm 80 is enveloped by 18-50 percent for the durations/areas shown. A check of the 48-hour and 72-hour, 10-mi^2 amounts for storm 80 (Table 10.12) shows the envelopments over moisture maximized values are as small as 8 and 5 percent, respectively. The envelopments of observed precipitation for storm 126 are the lowest of any storm in the sample and at 1-hour, 10-mi^2, the moisture maximized amount is the PMP estimate. These are very minimal envelopments, and reflect that this study indeed recognizes the importance of storms 80 and 126.

Table 13.5.--Comparison between general storm PMP and observed storm rainfalls or storms listed in Table 2.1 for selected durations and areas: (a) ratio of PMP to observed; (b) ratio of PMP to moisture maximized storm amount.

Storm No.	Lat. (Deg.	Long. Min.)	$10mi^2$, 1 hour		$10mi^2$, 24 hours		$1000mi^2$, 24 hours		$10,000mi^2$, 72 hours	
			(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
5	46 01	118 04	5.38	3.16	2.56	1.51	2.72	1.60	-	-
12	48 12	115 41	3.35	1.96	2.97	1.75	3.53	2.08	-	-
29	47 41	112 43	6.17*	3.63*	3.68*	2.16*	3.56*	2.09*	-	-
32	44 55	123 46	2.29	1.83	3.14	2.51	3.07	2.46	3.71	2.97
38	45 28	121 52	1.64	1.26	3.04	2.34	2.76	2.13	2.65	2.04
40	48 01	121 32	2.00	1.36	3.03	2.06	2.70	1.84	2.54	1.73
59#	46 00	118 00	2.48	1.76	2.71	1.94	2.73	1.95	-	-
60	47 28	123 35	2.96	1.92	4.47	2.91	4.37	2.84	-	-
66	42 10	124 15	2.84	1.86	2.80	1.83	2.86	1.87	4.29	2.80
74	46 10	122 13	3.16	2.42	3.76	2.87	3.46	2.64	3.13	2.20
78	46 25	123 31	3.23	2.11	4.17	2.73	3.71	2.42	3.78	2.47
80	47 28	123 43	1.95	1.18	2.29	1.41	2.12	1.31	2.40	1.48
82	47 22	115 26	3.67	2.29	2.54	1.58	3.17	1.98	-	-
88	45 55	123 38	2.93	1.91	3.19	2.07	4.00	2.60	3.64	2.37
106	44 16	112 04	2.02	1.19	2.28	1.35	1.84	1.08	-	-
126#	41 52	123 58	1.53	1.00	1.77	1.16	2.27	1.48	2.12	1.49
133	47 34	123 28	3.19	2.25	3.13	2.20	2.74	1.93	-	-
143	45 49	119 17	3.05	2.05	2.56	1.72	2.19	1.47	-	-
147	47 33	121 20	4.19	3.53	3.46	2.90	3.13	2.63	-	-
149	42 10	123 56	3.43	2.33	2.96	2.01	2.88	1.96	2.81	1.91
151	47 28	123 43	3.15	2.04	2.66	1.73	2.65	1.72	-	-
155	48 34	113 23	5.77*	3.39*	1.81*	1.07*	1.74*	1.02*	-	-
157	44 14	115 29	2.58	1.89	3.07	2.24	2.52	1.84	2.12	1.54
168	47 29	115 44	4.58	3.23	2.78	1.95	2.63	1.84	1.98	1.39
175	44 55	123 44	3.43	2.78	3.61	2.91	4.92	3.96	-	-
179	47 37	123 44	3.42	2.56	3.69	2.75	3.78	2.82	3.27	2.44

*From HMR 55A
#Seasonally adjusted using Figures 9.4-9.10

Comparison of storms from Table 2.1 versus PMP from this study can be shown in another format as in Table 13.6. In Section A of this table, the 10 greatest observed 10-mi^2 rainfall amounts (in inches) from the storm sample in Table 2.1 (west of the Cascade Mountains) were compared and have been ranked from highest to lowest for each duration from 1 to 72 hours and listed according to storm index numbers. In Section B, the observed amounts are given corresponding to the ranked order of storms in Section A. In the third set of data, Section C, values of PMP have been determined from the 10-mi^2 index map and depth-duration curves from Table 10.10 for the region corresponding to storm sites in Section A. Finally, in Section D, comparative ratios for PMP-observed storm values are given (Section C/Section B). Blanks occur for those storms not centered in the region (156 and 165).

The storms comprising Table 13.6 all occurred in the orographic region of the Cascades (Zone 4) and therefore the same depth-duration curve (Table 10.10) is applied to the 10-mi^2 index PMP values to obtain PMP estimates for the other durations in Section C. It was necessary to plot values and fit a smooth curve to get intermediate durations. One of the interesting features of this comparison is shown in Section D, where the ratios of PMP to observed storm data are listed. The ratios at each duration show a gradual increase, with some exceptions, as the storm rank increases from 1 to 10. The overall range of ratios is between 1.5 and 3.8 and is believed meteorologically reasonable.

Table 13.7 shows comparisons analogous to those in Table 13.6, but for orographic storms east of the Cascade Mountains. Only five storms (12, 59, 82, 157 and 168) are available in this storm sample. The range of PMP to observed storm ratios is 2.2 to 4.6, and is somewhat higher than those for storms west of the Cascades, at least for the highest ranked storms. Comparison of both the observed and PMP amounts (Section B and C) in this table against those in Table 13.6 shows a substantial decrease for the eastern storms.

From this comparison, it is concluded that the PMP analysis developed in this study provides a reasonable reflection of the maximized historical general type storms observed through the orographic part of the study region.

Although only two storms (106 and 143) have been considered as least orographic types in the storm sample, a comparison is made in Table 13.8, similar to those for the orographic storms. While the observed storm amounts are quite comparable to the orographic storms east of the Cascades in Table 13.7, the PMP estimates are lower between 12 and 24 hours. This results in the lower ratios of PMP to observed amounts shown in Section D. It has already been shown in Table 10.4 that local storm PMP at this site will provide adequate maximization.

Table 13.6.--Ten largest storms by duration for 10-mi^2 observations (see Appendix 2).

WEST OF THE CASCADES
Duration (Hours)

A	1	6	12	18	24	30	36	42	48	54	60	66	72
RANK	**Storm Numbers**												
1	156	80	126	126	156	156	156	80	80	80	80	80	80
2	126	126	80	156	126	126	80	156	156	156	156	156	156
3	80	32	156	80	80	80	126	126	126	126	126	126	126
4	38	156	133	151	151	133	133	88	133	88	179	88	88
5	32	151	151	133	133	88	88	133	88	165	165	179	40
6	40	66	32	165	149	151	32	179	32	179	32	165	179
7	165	133	165	149	88	149	179	60	179	32	88	40	165
8	60	165	66	32	32	32	149	32	165	149	149	32	32
9	133	38	149	88	165	165	151	165	149	66	40	149	149
10	88	60	88	66	66	179	165	149	60	74	74	74	74
B	**Observed depths (10-mi^2) corresponding to above ranked storms**												
1	2.05	6.65	11.47	13.47	16.23	18.53	20.74	25.20	28.07	29.79	30.12	31.68	34.39
2	1.84	6.44	9.17	13.08	15.84	16.50	20.10	24.21	26.13	27.13	27.42	27.89	30.29
3	1.70	6.41	8.76	12.69	14.45	16.39	17.96	18.96	19.37	19.98	20.69	20.93	21.17
4	1.54	5.70	8.02	10.45	12.45	13.36	15.12	16.19	17.27	17.26	17.69	19.49	20.36
5	1.46	4.74	7.91	10.15	12.16	13.13	15.05	16.10	17.26	16.89	17.62	18.90	19.31
6	1.30	4.50	7.58	9.11	10.90	12.96	13.55	14.27	15.32	15.58	17.41	18.83	19.28
7	1.27	4.28	7.19	8.89	10.76	12.01	13.17	14.00	15.29	15.49	17.26	17.67	19.02
8	1.22	4.21	6.71	8.45	10.66	11.95	13.00	13.84	14.95	15.46	16.43	17.43	17.43
9	1.19	4.01	6.27	8.26	10.63	11.20	12.98	13.80	14.72	14.72	16.14	16.74	16.85
10	1.17	3.82	5.80	8.20	9.63	10.86	12.38	13.67	14.24	14.23	14.98	16.02	16.66

Table 13.6.--(continued)

Duration (Hours)

	1	6	12	18	24	30	36	42	48	54	60	66	72
C	10-mi² PMP (at the corresponding storm site) from HMR 57 index map and depth-duration curves												
1	-	13.24	17.98	23.32	-	-	-	46.34	49.32	51.97	54.28	56.60	58.59
2	2.81	11.40	21.18	-	28.10	32.60	42.70	-	-	-	-	-	-
3	3.31	13.40	-	27.47	33.10	38.40	36.25	39.34	41.87	44.12	46.08	48.05	49.74
4	2.52	-	24.32	27.47	33.10	44.08	49.02	48.02	56.62	53.85	56.58	58.65	60.71
5	3.35	13.24	21.18	31.54	38.00	39.79	44.25	53.20	51.11	-	-	58.00	46.02
6	2.60	10.80	21.44	-	32.20	38.40	43.22	48.30	49.92	54.17	54.94	-	61.06
7	-	15.20	-	26.73	34.30	37.35	44.51	50.54	51.40	52.60	56.25	44.46	-
8	3.61	-	17.28	27.80	33.50	38.86	41.54	46.90	-	50.55	52.81	57.28	59.30
9	3.80	10.08	20.61	28.47	-	-	42.70	-	47.98	42.39	42.64	55.06	57.00
10	3.43	14.44	21.95	22.41	27.00	40.02	-	45.08	53.79	47.10	49.20	51.30	53.10
D	Ratio 10-mi² PMP to observed or C/B												
1	-	1.99	1.57	1.73	-	-	-	1.84	1.76	1.74	1.80	1.79	1.70
2	1.53	1.77	2.31	-	1.77	1.98	2.12	-	-	-	-	-	-
3	1.95	2.09	-	2.16	2.29	2.34	2.02	2.07	2.16	2.21	2.23	2.30	2.35
4	1.64	-	3.03	2.63	2.66	3.30	3.24	2.97	3.28	3.12	3.20	3.01	2.98
5	2.29	2.79	2.68	3.11	3.13	3.03	2.94	3.30	2.96	-	-	3.12	2.38
6	2.00	2.40	2.83	-	2.96	2.96	3.19	3.38	3.26	3.48	3.16	-	3.17
7	-	3.55	-	3.01	3.19	3.11	3.38	3.61	3.36	3.40	3.26	2.52	-
8	2.96	-	2.58	3.29	3.14	3.25	3.20	3.39	-	3.27	3.21	3.29	3.40
9	3.19	2.51	3.29	3.44	-	-	3.29	-	3.26	2.88	2.64	3.29	3.38
10	2.93	3.78	3.78	2.73	2.80	3.68	-	3.30	3.78	3.31	3.28	3.20	3.19

Table 13.7.--Ranked largest storms by duration for 10-mi² observations (see Appendix 2).

EAST OF THE CASCADES
Duration (Hours)

A	1	6	12	18	24	30	36	42	48	54	60	66	72
RANK	Storm Numbers												
1	157	157	157	157	157	59	157	157	157	157	157	157	157
2	59	59	59	59	59	157	59	59	168	168	168	168	168
3	12	82	82	82	168	168	168	168	12	59	59	-	-
4	82	168	168	168	82	12	12	12	59	-	-	-	-
5	168	12	12	12	12	-	-	-	-	-	-	-	-
B	Observed depths (10-mi²) corresponding to above ranked storms												
1	0.93	3.20	3.43	3.68	4.89	5.49	6.37	7.53	7.87	8.13	8.26	8.40	8.87
2	0.84	2.06	3.14	3.50	4.79	5.32	5.79	5.87	6.43	6.92	7.45	7.95	8.24
3	0.55	2.03	3.01	3.44	4.42	4.91	5.42	5.84	6.34	6.00	6.00	-	-
4	0.45	1.52	2.82	3.43	4.06	4.19	4.79	5.57	5.96	-	-	-	-
5	0.43	1.47	2.20	3.05	3.87	-	-	-	-	-	-	-	-
C	10-mi² PMP (at the corresponding storm site) from HMR 57 index map and depth duration curves												
1	2.40	7.80	10.95	13.20	15.00	13.20	17.70	18.75	19.65	20.40	20.85	21.30	21.75
2	1.92	6.24	8.76	10.56	12.00	16.50	14.16	15.00	16.11	16.73	17.10	17.47	17.84
3	1.84	5.36	7.52	9.06	12.30	13.53	14.51	15.38	15.07	16.32	16.68	-	-
4	1.65	6.40	8.98	10.82	10.30	12.65	13.57	14.38	15.72	-	-	-	-
5	1.97	5.98	8.40	10.12	11.50	-	-	-	-	-	-	-	-
D	Ratio - 10-mi² PMP to observed storm (or C/B)												
1	2.58	2.44	3.19	3.59	3.07	2.40	2.78	2.49	2.50	2.51	2.52	2.54	2.45
2	2.29	3.03	2.79	3.02	2.50	3.10	2.45	2.56	2.51	2.42	2.30	2.20	2.17
3	3.35	2.64	2.50	2.63	2.78	2.76	2.68	2.63	2.38	2.72	2.78	-	-
4	3.67	4.21	3.18	3.15	2.54	3.02	2.83	2.58	2.64	-	-	-	-
5	4.58	4.07	3.82	3.32	2.97	-	-	-	-	-	-	-	-

Table 13.8.--Ranked largest least-orographic storms by duration.

	RANK	1	6	12	18	24	36
		DURATION (HOURS)					
A		**Storm Numbers**					
	1	106	106	106	106	106	-
	2	143	143	143	143	143	-
B		**Depths (10-mi^2) corresponding to above ranks (observed)**					
	1	0.96	2.70	3.04	3.91	4.25	-
	2	0.57	1.98	3.03	3.21	3.40	-
C		**10-mi^2 PMP from HMR 57 index map**					
	1	11.94	5.72	7.86	8.92	9.70	-
	2	1.74	5.13	7.05	8.00	8.70	-
D		**Ratio 10-mi^2 PMP to observed storm (or C/B)**					
	1	2.02	2.12	2.58	2.28	2.28	-
	2	3.05	2.59	2.33	2.49	2.56	-

13.5 Comparison of PMP Change with Time

Both as a point of interest and as a means of understanding the level of PMP finally achieved in this study, it was decided to examine the chronological variation in PMP estimates for at least one specific drainage within this region. The Elk Creek Lake Basin (127-mi^2) is a tributary to the Rogue River in western Oregon (orographic subregion 4). Table 13.9 lists PMP estimates that have been made by the NWS over time for this drainage.

Table 13.9 is interesting from the standpoint that over the 28-year history of PMP estimates for the Elk Creek Lake Basin, the latest estimates are on the order of some of the earlier estimates (3/65 and 8/67). This does not however, justify the correctness of the result, but is an unplanned consequence of the study, and is offered as an example that PMP estimates do not always increase over time.

Table 13.9.--Chronological variation of PMP estimates made for the Elk Creek drainage, Oregon (42.7°N, 122.72°W, 127-mi²).					
	Duration				
Date	6	24	48	72	Reference
3/65	5.90	15.70	23.40	28.10	Myers, 1965
11/66	6.19	16.67	25.09	30.37	HMR 43
8/67	4.61	10.38	19.53	24.00	COE ltr, 1982
12/82	7.80	19.50	27.10	32.50	Miller, 1982
10/93	5.56	14.06	21.13	25.21	HMR 57

13.6 Comparison Between Adjoining Drainages

Another comparison made possible by the selection of drainages by Reclamation in Chapter 12, is that between the Cedar River, the Green River and the White River (Mud Mountain Dam), in western Washington. These three basins adjoin one another from north to south along the west slopes of the Cascades to the north of Mount Rainier. Their areas are 81-, 221- and 402-mi², respectively. A comparison was made in the course of the evaluations discussed in Chapter 12, between results obtained from the present study, from HMR 43, and from NOAA Atlas 2, as shown in Table 13.10.

Table 13.10.--Comparison between basin-average estimates for three neighboring drainages.				
		Duration (hours)		
Drainage	Study	1	6	24
Cedar River (81-mi²)	HMR 43	2.18	7.85	23.56
	HMR 57	2.12	7.29	18.40
	NOAA Atlas 2	0.88	3.15	7.52
Green River (221-mi²)	HMR 43	*	6.31	18.87
	HMR 57	1.77	6.09	15.76
	NOAA Atlas 2	0.78	2.52	5.89
White River (402-mi²)	HMR 43	*	6.11	18.64
	HMR 57	1.62	5.67	14.71
	NOAA Atlas 2	0.73	2.32	5.00
* HMR 43 does not give 1-hour PMP for areas >100-mi²				

The comparisons shown in Table 13.10 are not as significant as others, but can be used more to check consistency. In this regard, ratios can be formed between the individual PMP estimates and the NOAA Atlas 2 amounts. It is reasonable to expect that these ratios should show a degree of consistency.

13.7 Comparison Between Neighboring Studies

The Northwest study region is surrounded by the Pacific Ocean, Canada, and the remainder of the United States. HMR 55A, HMR 49 and HMR 36 cover the United States portion of the region bordering the Northwest and have already been referred to many times throughout this study. This section will show how well the new results agree with two of these neighboring studies; HMR 36 is currently undergoing revision and comparisons to HMR 36 at this point were not made.

13.7.1 Comparison to HMR 55A

One of the ground rules in the development of this study was that it was to be done independently of its neighboring studies. However, the techniques used in its development closely followed those used in preparation of HMR 55A. Storms 29 and 155 occurred along the western limits of HMR 55A in Montana and were included in the current storm sample (Table 2.1) to establish some continuity between these two studies.

After the initial 10-mi^2, 24-hour PMP index analysis was drawn, minor adjustments were made along the mutual border with HMR 55A to provide continuity. A number of comparisons were made along the mutual border (Continental Divide) in order to evaluate the differences. Close agreement was found between the results from HMR 55A and the present study for all durations 24 hours and longer, at all area sizes. Differences were noted at shorter durations, where current 1-hour results were as much as 30 percent lower to 15 percent higher than results in HMR 55A, depending on area size. This occurs because of differences in short duration depth area and depth-duration decisions made between the two studies.

Comparisons were also made between local storm PMP estimates determined along the Continental Divide from the two studies. Although the current local storm index map was based on information available from Northwest storms, the 1-hour, 1-mi^2 index values are in reasonable agreement (less than 5 percent differences). However, the decision to go with a 6-/1-hour ratio of 1.15 for the present study (as compared to the 1.35 used in HMR 55A) will result in significant differences at 6 hours between the two studies.

13.7.2 Comparison to HMR 49

A comparison was also made between PMP estimates from this study and those from HMR 49 in a manner similar to that described for HMR 55A. Here the common border essentially follows 42°N, but varies somewhat toward the eastern limits as it follows the Snake River drainage bounds.

HMR 49 was not derived from a base of storm DAD data and therefore close agreement was not expected. Furthermore, HMR 49 does not permit 1-hour general storm PMP estimates to be determined directly. Between 6 and 72 hours and for areas to 1000-mi^2, differences on the order of ± 20 percent were determined.

Local storm PMP estimates were compared for the common border between this study and HMR 49. At 1 hour, the variation between studies is about 20 percent near the California border, decreasing to near 5 percent near the Idaho-Utah border. As with the HMR 55A comparison, the low 6-/1-hour ratio in the present study results in lower 6-hour values than are found in HMR 49. However, the differences are only on the order of 3 to 10 percent since the 1-hour local storm PMP in the present study are everywhere higher than in HMR 49.

14. CONCLUSIONS AND RECOMMENDATIONS

This report has provided the rationale and procedure by which the PMP for the Northwestern states and southern British Columbia has been revised. The method of analysis has generally followed the process developed for HMR 55A, PMP for the east slopes of the Rocky Mountains (Hansen et al., 1988). The report includes extensive comparisons of basin PMP between this study and its predecessor, HMR 43 (Chapter 12). PMP estimates from this study are also compared against a number of other indices (Chapter 13), with the intent of evaluating the level of magnitude derived.

Among the important achievements and conclusions established by this study are the following:

1. Established a computerized procedure to routinely analyze major storms that have affected the region. The storm analysis procedure was carried out for 28 major storms affecting the Pacific Northwest in a consistent, detailed way.

2. Developed depth-area-duration and mass curves for the 28 U.S. major storms and for multiple centers within each storm where applicable in and near the Pacific Northwest (Appendix 2).

3. Provide all-season general storm PMP estimates. Developed seasonal adjustments to PMP using historical precipitation data from as early as the late 19th century. Separate maps are included that provide seasonal adjustments to PMP.

4. Developed new climatologies of 12- and 3-hour maximum persisting dew points.

5. Established PMP for the Pacific Northwest that is consistent at the interface with the PMP for HMR 55A.

6. General storm PMP estimates from this study are larger than HMR 43 estimates in most orographic regions, while being somewhat lower than HMR 43 estimates in least orographic regions.

7. Extended local-storm PMP estimates to west of the Cascade Mountains.

8. Conducted extensive climatic research to establish a new 6/1-hour ratio for local storms in the region. Developed a basic synoptic climatology of conditions favorable for extreme local storms in the Pacific Northwest.

9. Used 3-hour persisting 1000-mb dew points to better estimate the moisture available for local storms.

10. Local storm PMP for 1 hour are somewhat higher in the southern portion of the study area than was provided in HMR 43, and slightly less in the north. At 6 hours PMP is usually less, owing to the reduced 6/1-hour ratio.

11. The ratios between PMP and 100-year precipitation values from NOAA Atlas 2 are consistent with similar comparisons made in other parts of the western U.S.

12. The PMP generated by this study represents the best available estimates for the region, and should be applied to all future design studies.

13. The estimates available from this study represent generalized basin results and should form the basis for site-specific applications.

14. The procedures provided in Chapter 15 are relatively simple to apply, and cover both general storm and local storm PMP applications.

As a consequence of this study, the following recommendations are made:

1. That future effort be made to determine appropriate procedures to enable areal and temporal distribution to be developed based on input from this study.

2. That information be determined that will provide seasonal snowmelt and temperature sequences that can be combined with PMP estimates from this study. Similar interest may require that a future study consider the probable maximum snowpack and the corresponding maximum rainfall that can be combined for that season.

3. That NWS develop the automated capability to process storms to determine the appropriate depth-area-duration information. The joint effort between NWS and USBR used in this study, although practical as an "interim" measure, is awkward and inefficient for future studies.

4. That studies on antecedent precipitation be carried out for this region. This study would look at basin and storm area sizes, seasonality and geographic variation of antecedent precipitation.

15. COMPUTATIONAL PROCEDURE

15.1 Introduction

This chapter is intended to provide the user with specific information through a stepwise format that leads to determination of both general and local storm PMP for a particular location within the Pacific Northwest (Figure 15.1). All the tables and figures contained in this chapter have been presented in previous chapters, and are repeated here to aid in making expedient estimates.

The information in this chapter is applicable to general storm PMP for durations between 1 and 72 hours over areas between 10 and 10,000-mi^2, and to local storms between 1/4 and 6 hours for areas between 1 and 500-mi^2. When making PMP estimates for basins less than 500-mi^2 in an area, it is recommended that both general and local storm PMP be calculated. The larger of the two estimates should be taken to represent the basin PMP in most cases. Since the decisions regarding which results are most critical to the basin involve hydrological considerations applicable to the probable maximum flood (PMF), further clarification is left to the end users. This study is limited to aspects of PMP determination only.

Seasonal variation, temperature and wind distributions, along with limited information on temporal and spatial distributions, has also been included in this chapter. This information may aid the user in applications where snowmelt/PMP considerations are important, or in deciding where to place storm maxima within a basin or in establishing temporal sequences. The temporal and snowmelt information for general storms contained here was taken directly from HMR 43, since it was not one of the stated objectives of the present study to update this material. It remains for further study to provide improved procedures regarding snowmelt, and general storm temporal and spatial distributions.

The computational procedure developed for this study has been kept simple and straightforward. Index PMP maps were drawn for the general storm at 1:1,000,000 scale for user convenience. These index PMP maps are presented as Maps 1 to 4. Each map includes overlaps of at least 1/2 degree with its neighboring map(s). These oversized maps are located in a folder accompanying this report.

The index PMP maps contain substantial background information to aid the user in determining relative locations. To this end, latitude and longitude marks are included, as are county boundaries, the Cascade Mountain ridgeline and selected major cities and towns. In addition, each index map contains the respective subregional boundaries (identified in Chapter 10) used in depth-duration computations.

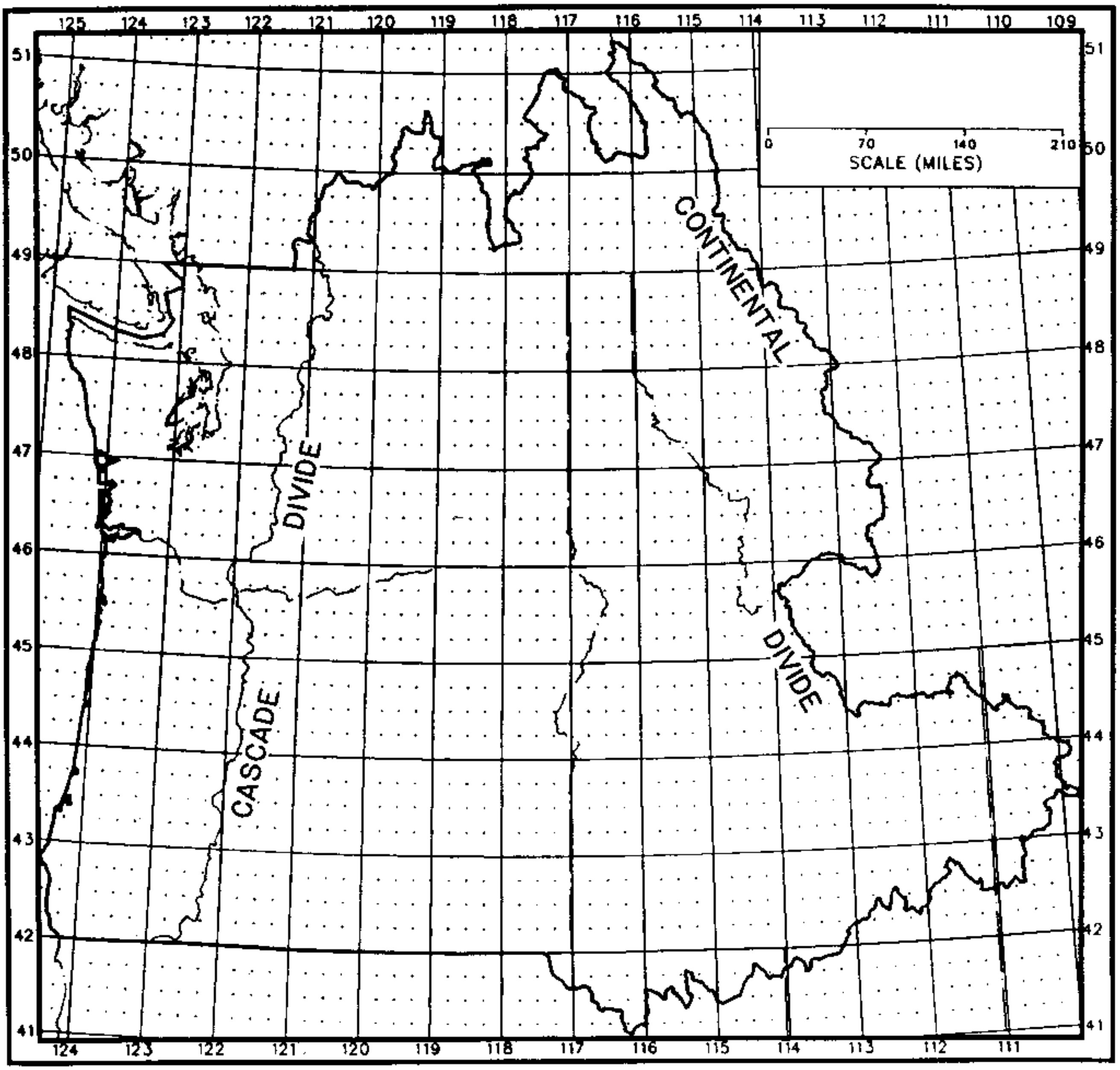

Figure 15.1.--Base map of Pacific Northwest region included in this study.

The following sections present the individual stepwise procedures for determining both general and local storm PMP, together with a worked example for each. Although the examples are meant to clarify the recommended steps for this study, they may not demonstrate every complication to be encountered in this region. The user is cautioned that this procedure is a general guide to PMP for the region and specific basins may need to be examined in more detail. In such instances, the user needs to consult with the Hydrometeorological Branch staff of the National Weather Service.

15.2 General Storm Procedure

Step

1. **Drainage outline**

   Trace the outline of the drainage (at 1:1,000,000 scale) onto a transparent overlay.

2. **User decision**

   Decide which result is needed for the application of interest; all-season PMP (then step 4 can be skipped) or seasonal PMP.

3. **All-season index PMP estimate**

   Place the drainage overlay from step 1 on the corresponding all-season 10-mi^2, 24-hour PMP index map section (Charts 1 to 4 attached to this report), and make a uniform grid that covers the drainage. Obtain index map estimates of PMP for each grid point and determine the drainage average 10-mi^2, 24-hour PMP amount. The choice of grid size is left to the user, but consideration should be given to the gradient of PMP throughout the particular drainage, such that the grid spacing will provide reasonably representative results. For drainages with steep or irregular gradients and for drainages larger than about 1000 mi^2, the 24-hour PMP isohyets can be traced on the overlay to allow computation of an integrated areal average. Software is also available commercially that can be used to determine the areal average depths.

4. **Seasonal index PMP estimates**

   Use of this option implies some knowledge of seasonal snowmelt that will be combined with seasonal PMP estimates. If the seasonal variation of PMP is needed, the procedure recommended is to obtain monthly drainage average PMP estimates using the seasonal maps in Figures 15.2-15.8 in the manner described for all-season estimates in step 3. These maps are reproduced at 1:8,000,000 scale to facilitate enlargement to the scale of the index maps. This should allow better estimate of the corresponding average percentage for the drainage of interest. The resulting monthly estimates can be plotted and a smooth curve drawn to verify consistency and provide for temporal interpolation. The user is reminded that in Figures 15.2-15.8, any portion of a drainage covered by an isoline of 90 percent or higher is treated as equivalent to the all-season value. Multiply the all-season PMP average from step 3 by the percentage determined from this step.

5. **Depth-duration**

As discussed in Section 10.3, depth-duration varies according to regional subdivisions shown in Figure 15.9. These subregions are also delineated on charts 1 to 4. For the subregion containing the drainage of interest, read the corresponding depth-durational ratios from Table 15.1 and multiply each by the 24-hour results obtained from either step 3, or step 4. In the event that a particular drainage involves more than one subregion, obtain proportionately weighted results.

Table 15.1.--Adopted depth-duration ratios of 24-hour amounts for subregions in Figure 15.9 (Section 10.3.2.).

Subregion	Duration (hours)				
West of Cascades	1	6	24	48	72
4	.10	.40	1.00	1.49	1.77
5	.11	.43	1.00	1.37	1.58
3	.12	.44	1.00	1.23	1.35
East of Cascades					
1	.16	.52	1.00	1.40	1.55
2	.16	.52	1.00	1.31	1.45
6	.18	.55	1.00	1.27	1.37
7	.20	.59	1.00	1.20	1.30

6. **Areal reduction factors**

Take the 1-, 6-, 24-, 48- and 72-hours, 10-mi^2 basin average estimates from step 5, and use Figure 15.10 (orographic) or Figure 15.11 (least orographic) to determine areal reduction percentages for the drainage of interest. Multiply these reduction percentages by the corresponding 10-mi^2 amounts from step 5. If a particular drainage includes both orographic and least orographic subregions, again use proportionately weighted results.

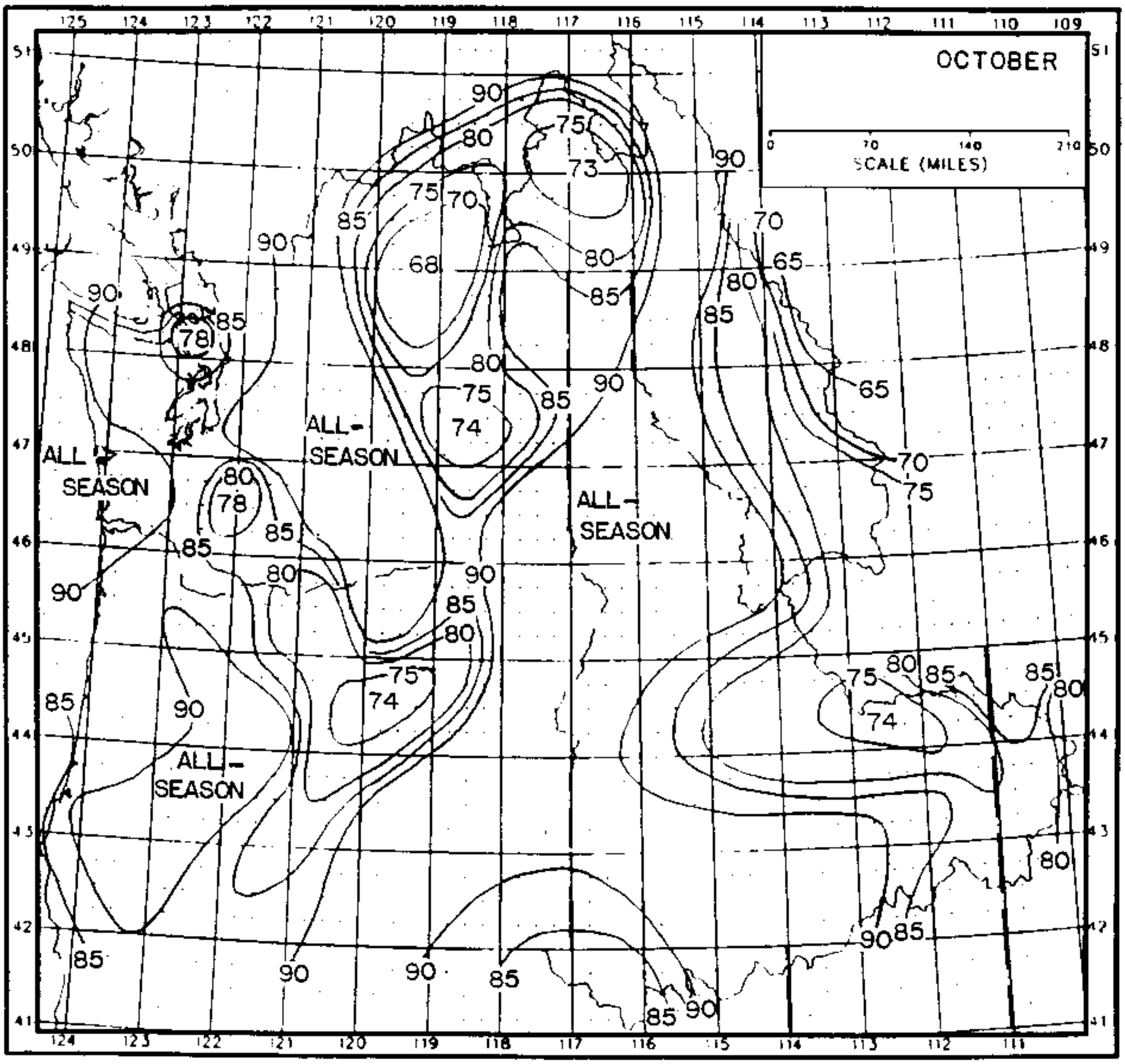

Figure 15.2.--Seasonal percentage variation of PMP for October based on all-season index maps provided in this study (Section 9.2.2).

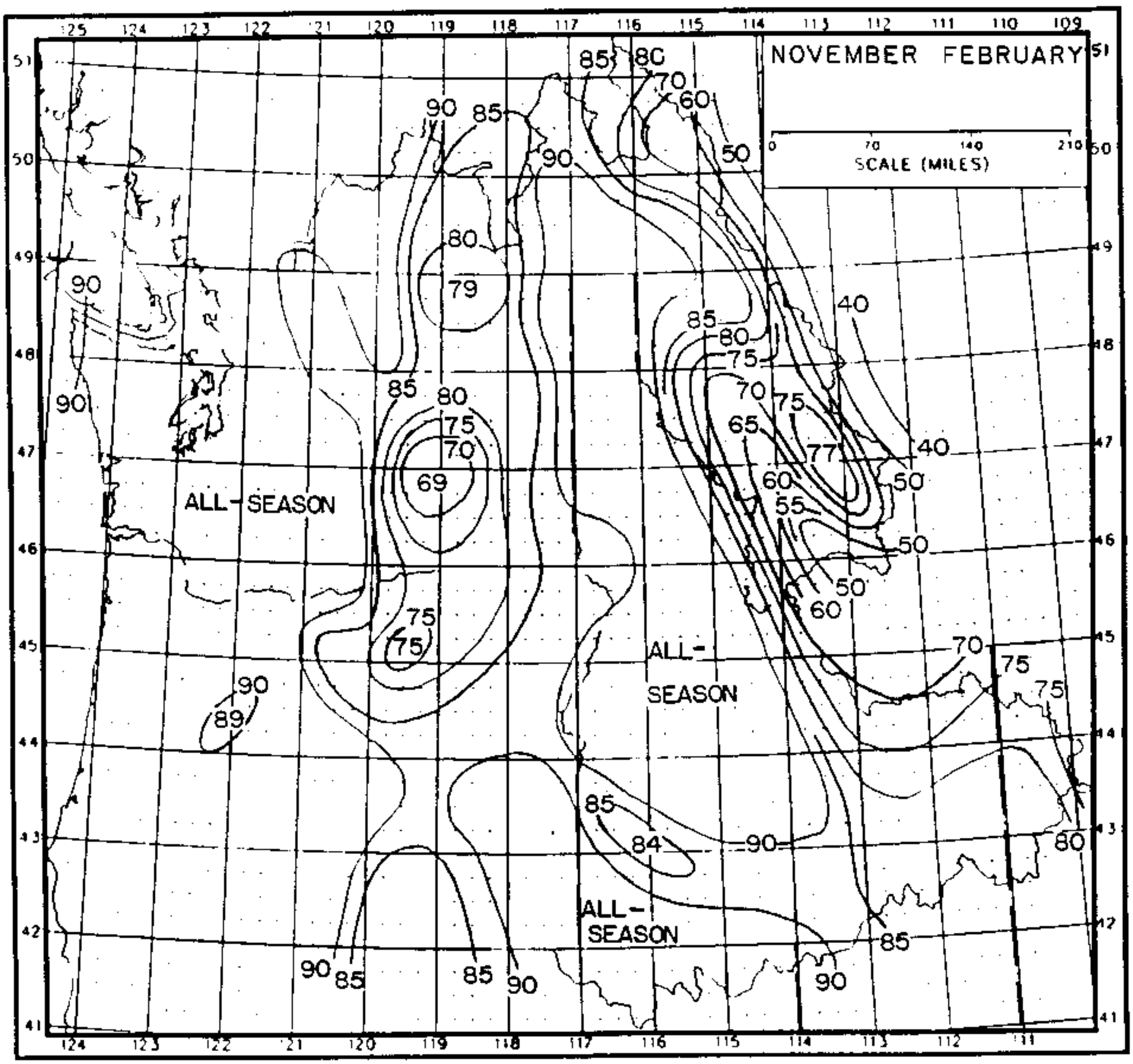

Figure 15.3.--Same as Figure 15.2 - for November through February (Section 9.2.2).

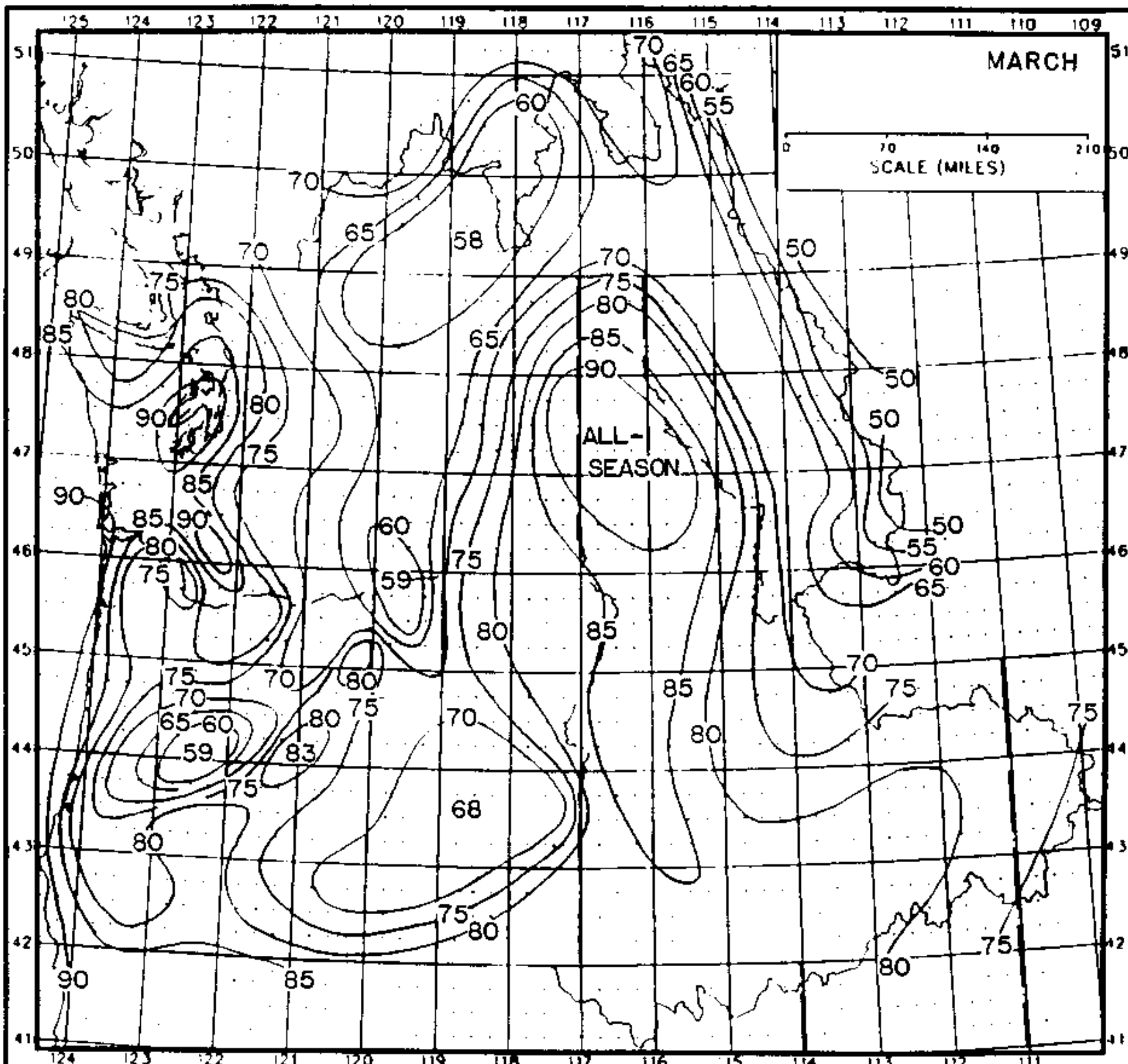

Figure 15.4.--Same as Figure 15.2 - for March (Section 9.2.2).

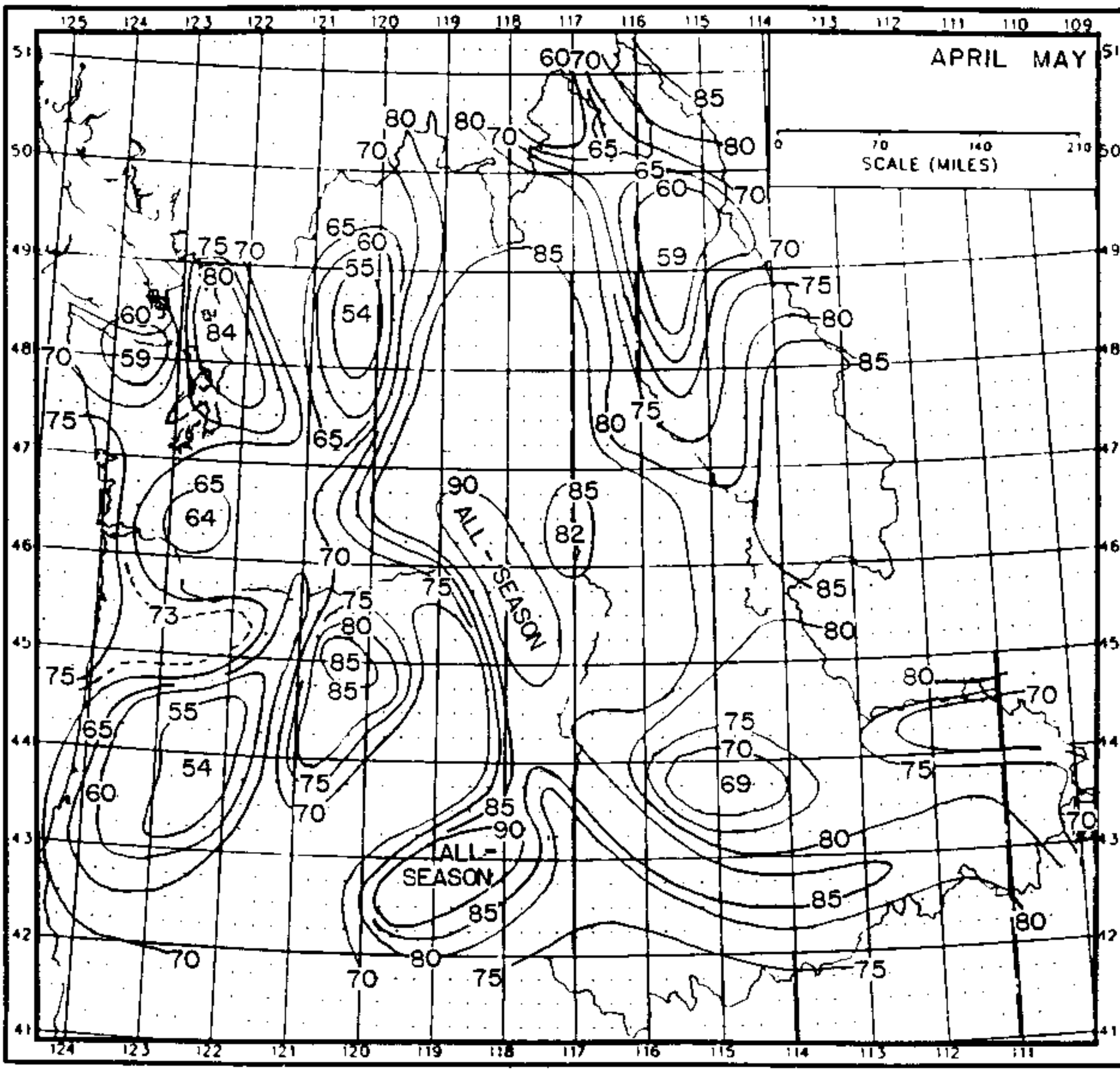

Figure 15.5.--Same as Figure 15.2 - for April through May (Section 9.2.2).

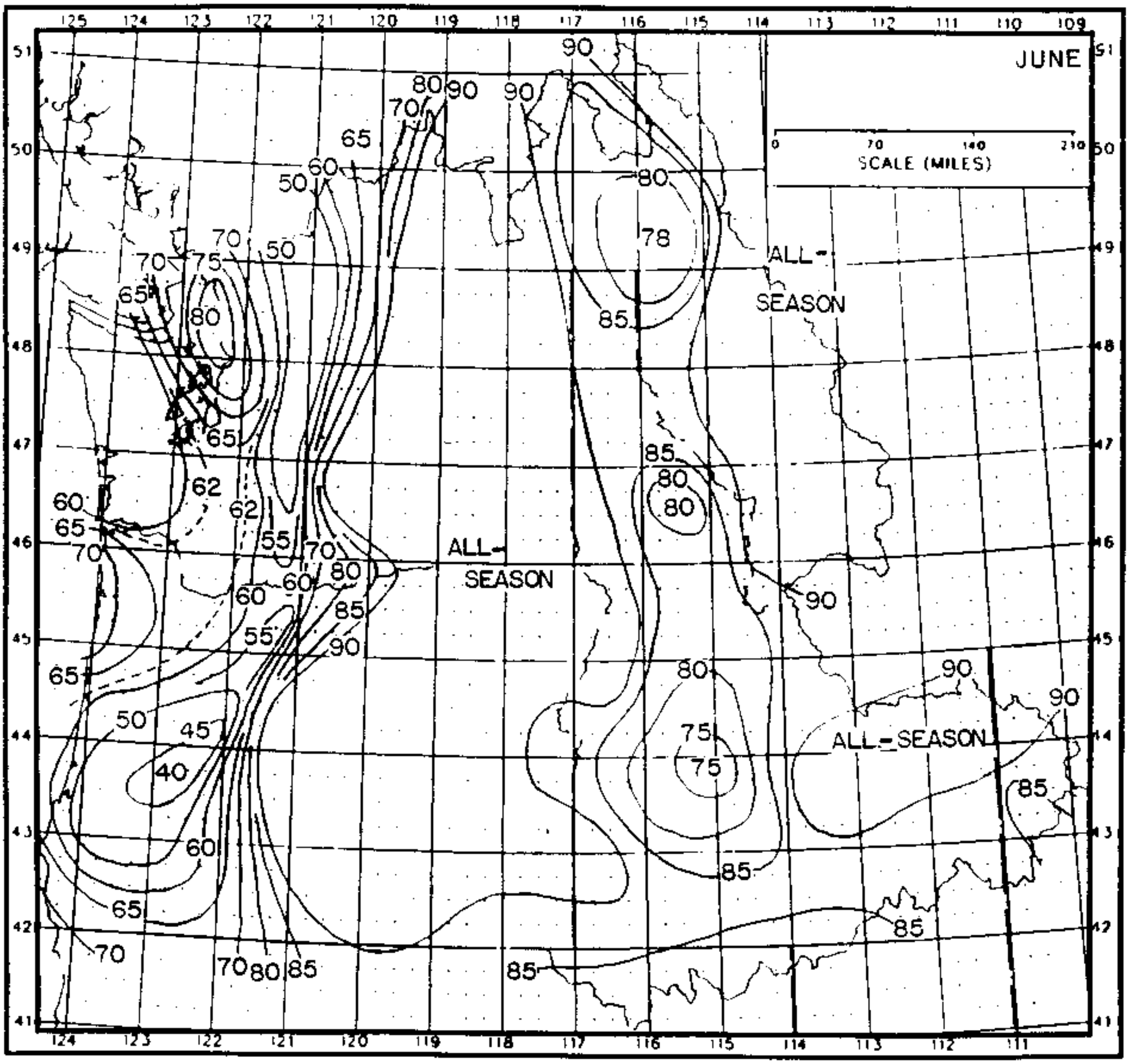

Figure 15.6.--Same as Figure 15.2 - for June (Section 9.2.2).

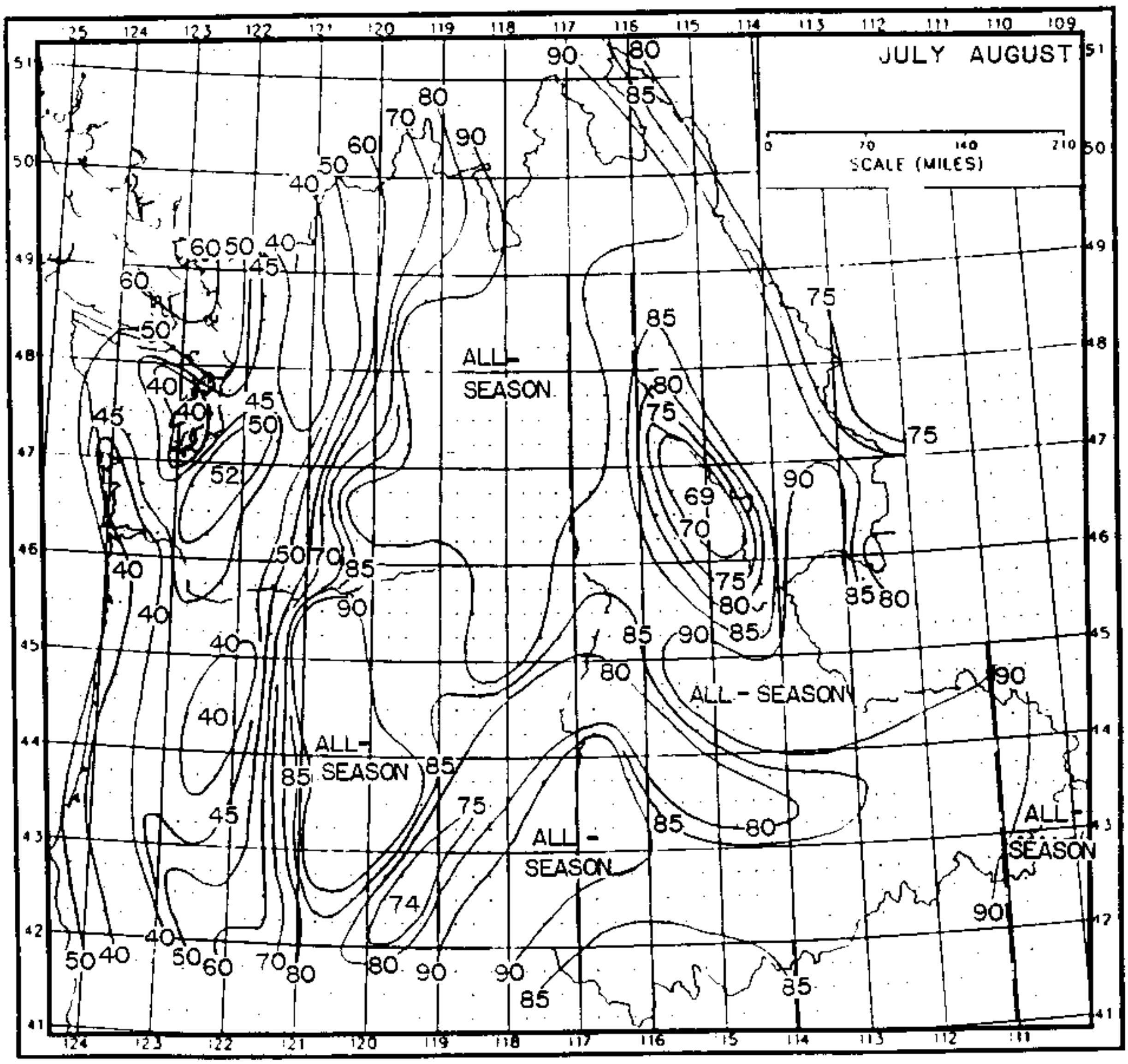

Figure 15.7.--Same as Figure 15.2 - for July through August (Section 9.2.2).

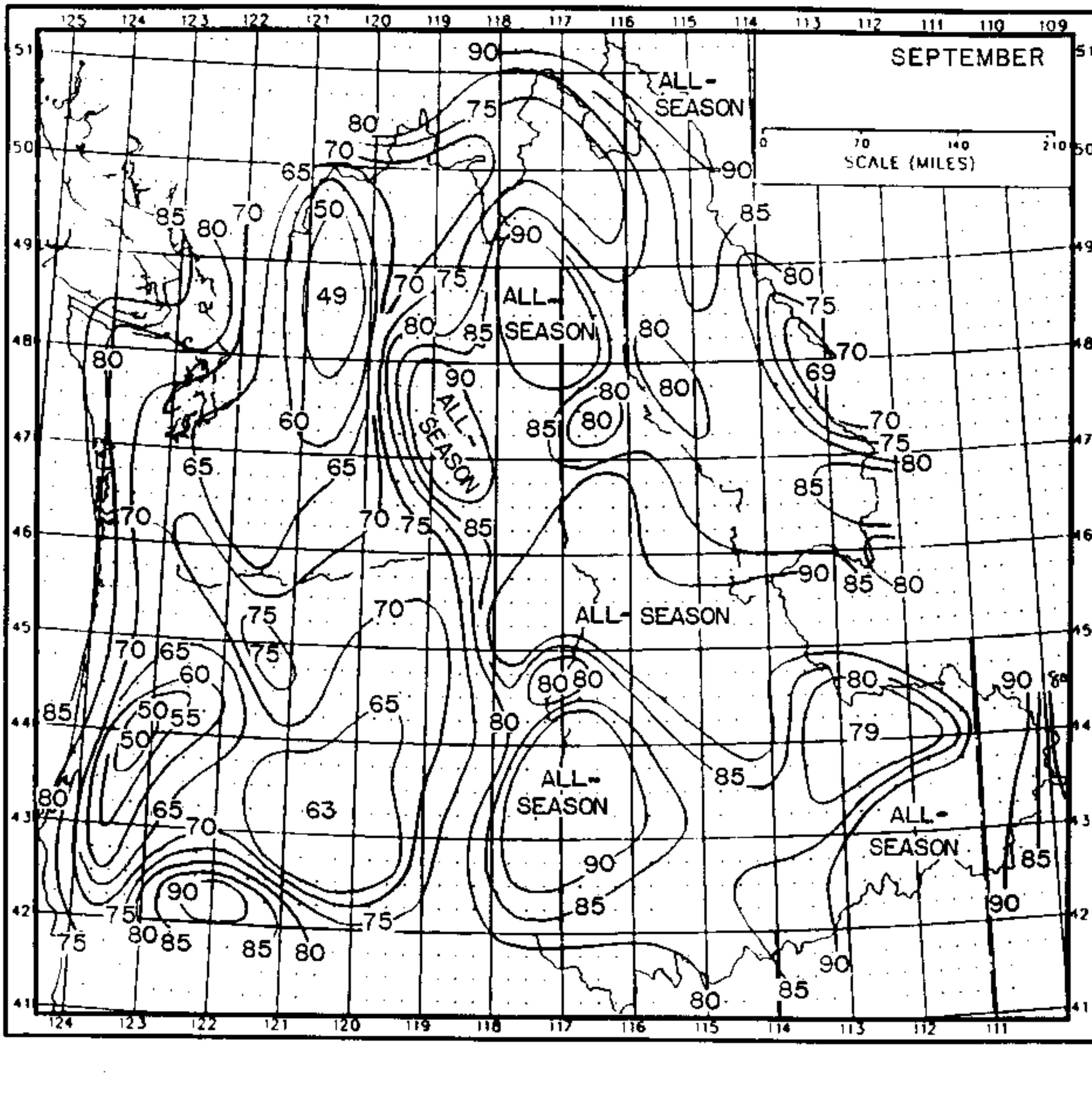

Figure 15.8.--Same as Figure 15.2 - for September (Section 9.2.2).

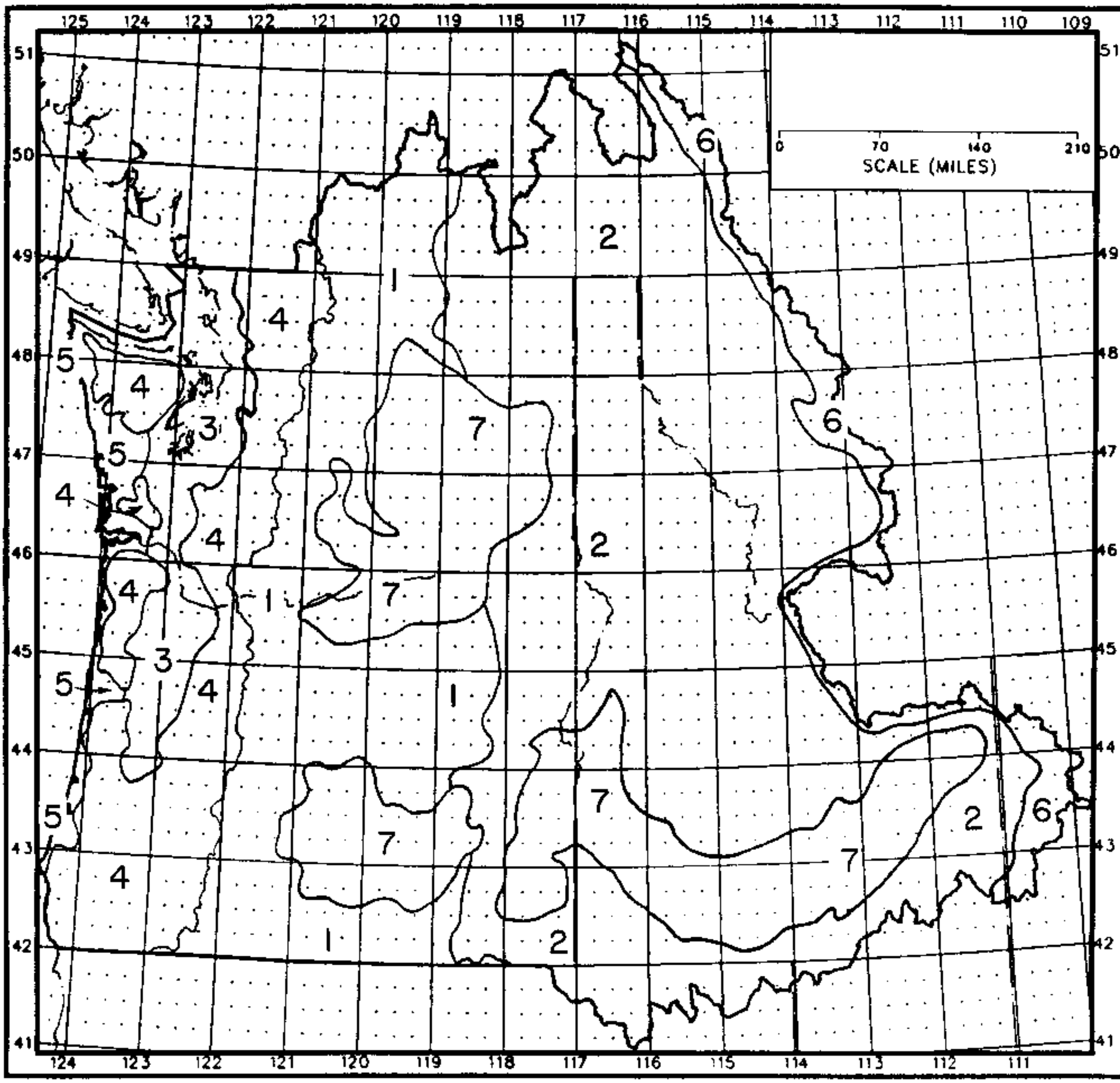

Figure 15.9.--Subregions adopted for this study; 1 = east slopes of the Cascades, orographic; 2 = orographic; 3 = least orographic, west of the Cascades; 4 = orographic, west of Cascades ridgeline; 5 = coastal orographic; 6 = west slopes of the Rockies, orographic, and 7 = least orographic, east of the Cascades (Section 10.3.2).

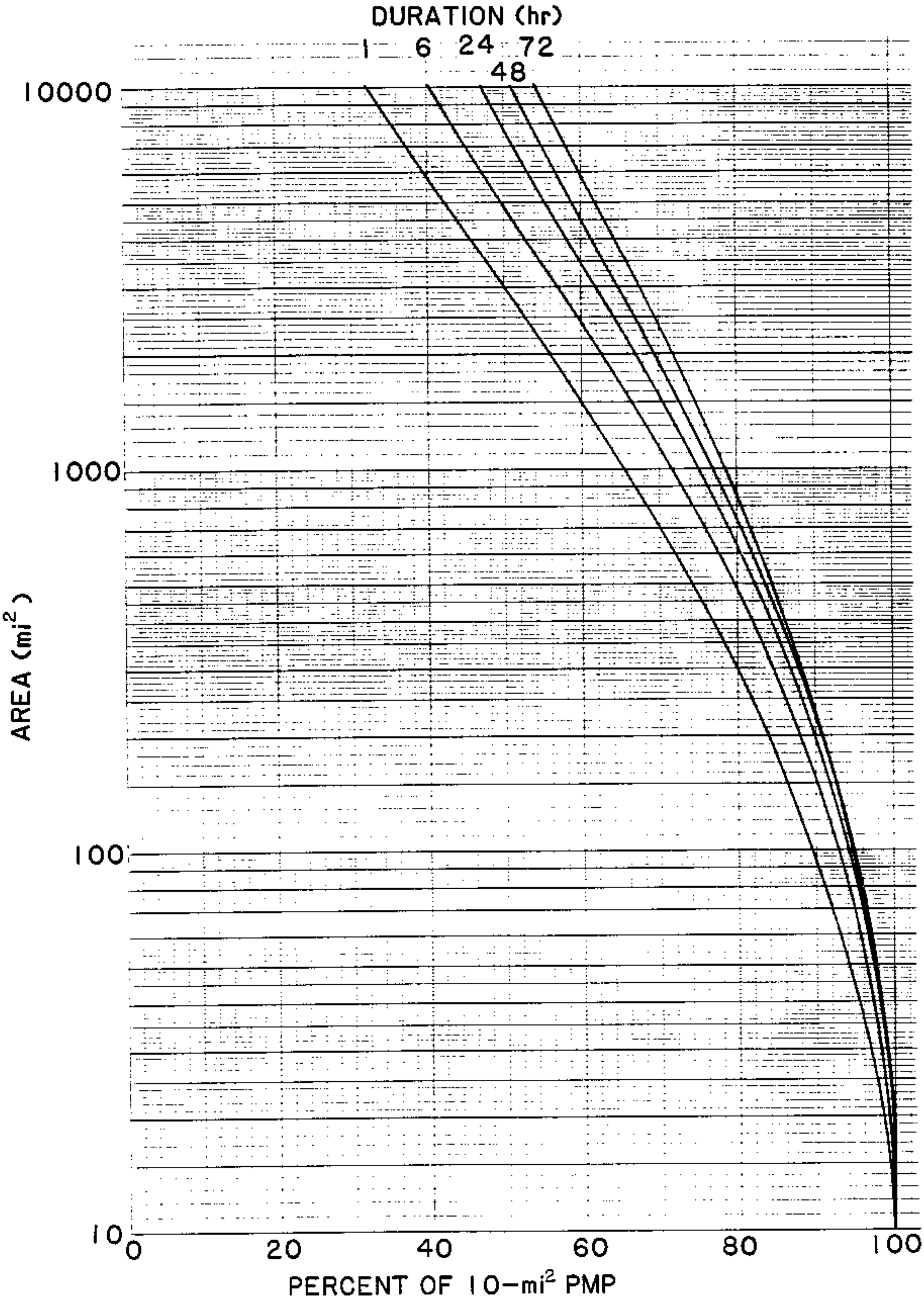

Figure 15.10.--Adopted depth-area relations for orographic subregions (Section 10.2.1).

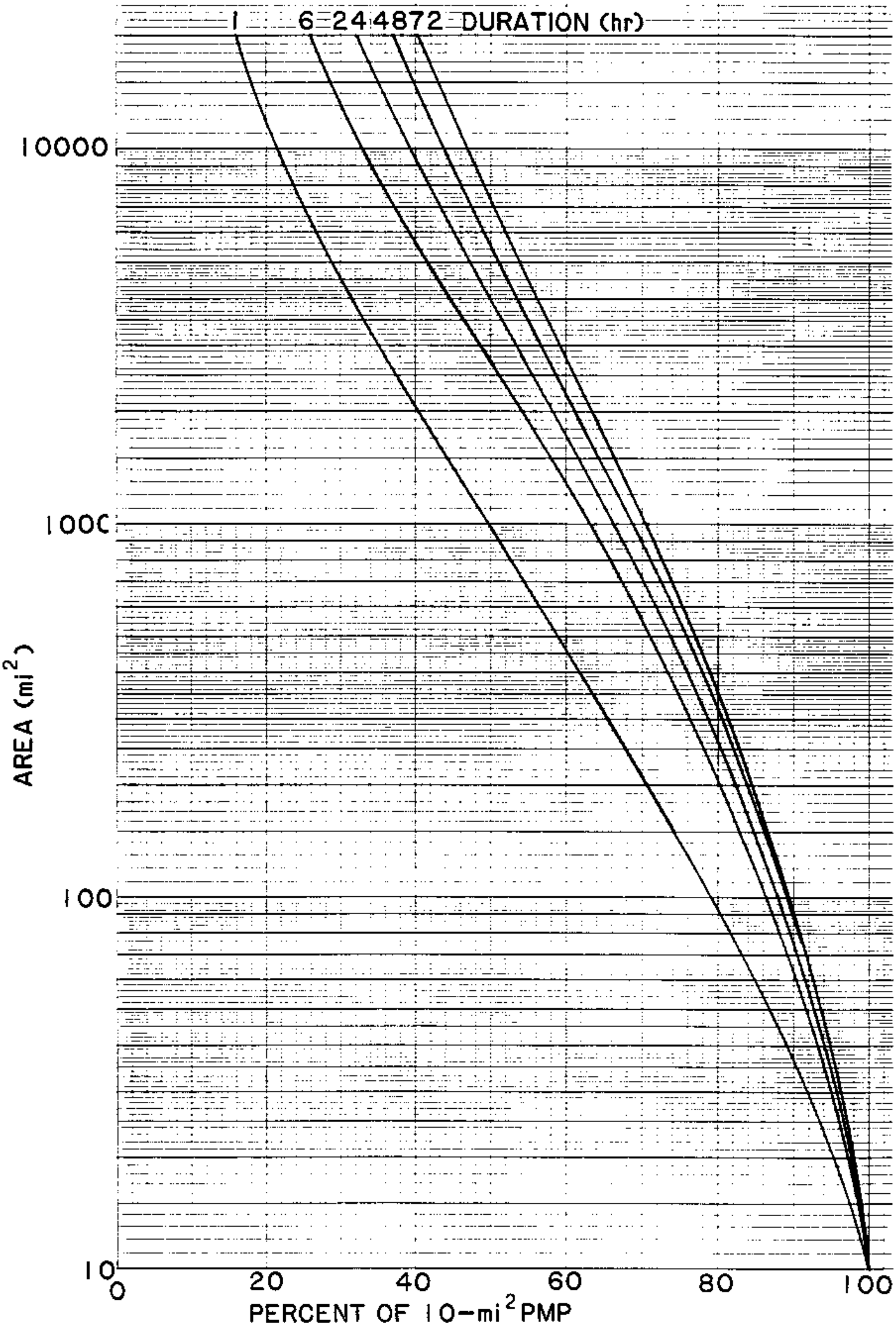

Figure 15.11.--Adopted depth-area relations for least orographic subregions (Section 10.2.2).

7. **Incremental estimates**

If incremental values for the various durations are desired, it is necessary to plot the results from step 6 and draw a smooth curve in order to read off intermediate 6-hour values. Subtract each 6-hour depth from the depth of the next longer duration. Some applications may require hourly increments (user decision), and are obtained from smooth depth duration curves, as for 6-hour values.

8. **Temporal distribution (from Section 6-B, HMR 43)**

The temporal distribution represents the sequential order of increments of PMP that is considered most critical for determining the probable maximum flood hydrograph. The order of increments is referred to as follows: The largest increment (customarily for 6 hours) is referred to as the first increment and the lowest or smallest increment is the 12th (for a 72-hour sequence). Similar rankings are used when hourly increments are needed. Storm sequences have been examined to identify certain characteristic groupings of increments and are presented here as guidelines the user may follow in developing the most critical sequence for a specific application.

(a) Group the four largest 6-hour increments (in a 72-hour sequence) together, the middle four increments in another group and the lowest four increments in a third group.

(b) Within each of these 24-hour groups, arrange the four increments such that the second largest increment is next to the largest, the third largest is joined to the first pairing and the fourth largest is at either end. In most 72-hour storms (although not discussed in HMR 43), the evidence indicates that the highest 24-hour group does not occur in the first 24 hours of the sequence.

(c) Arrange the three 24-hour groups so that the second highest 24-hour group adjoins the highest 24-hour group, with the third group at either end.

A series of examples are shown in Figure 15.12 that demonstrate some of the possible combinations resulting from these guidelines. It is left to the user to identify which sequence will provide the temporal distribution most critical to the specific drainage of interest.

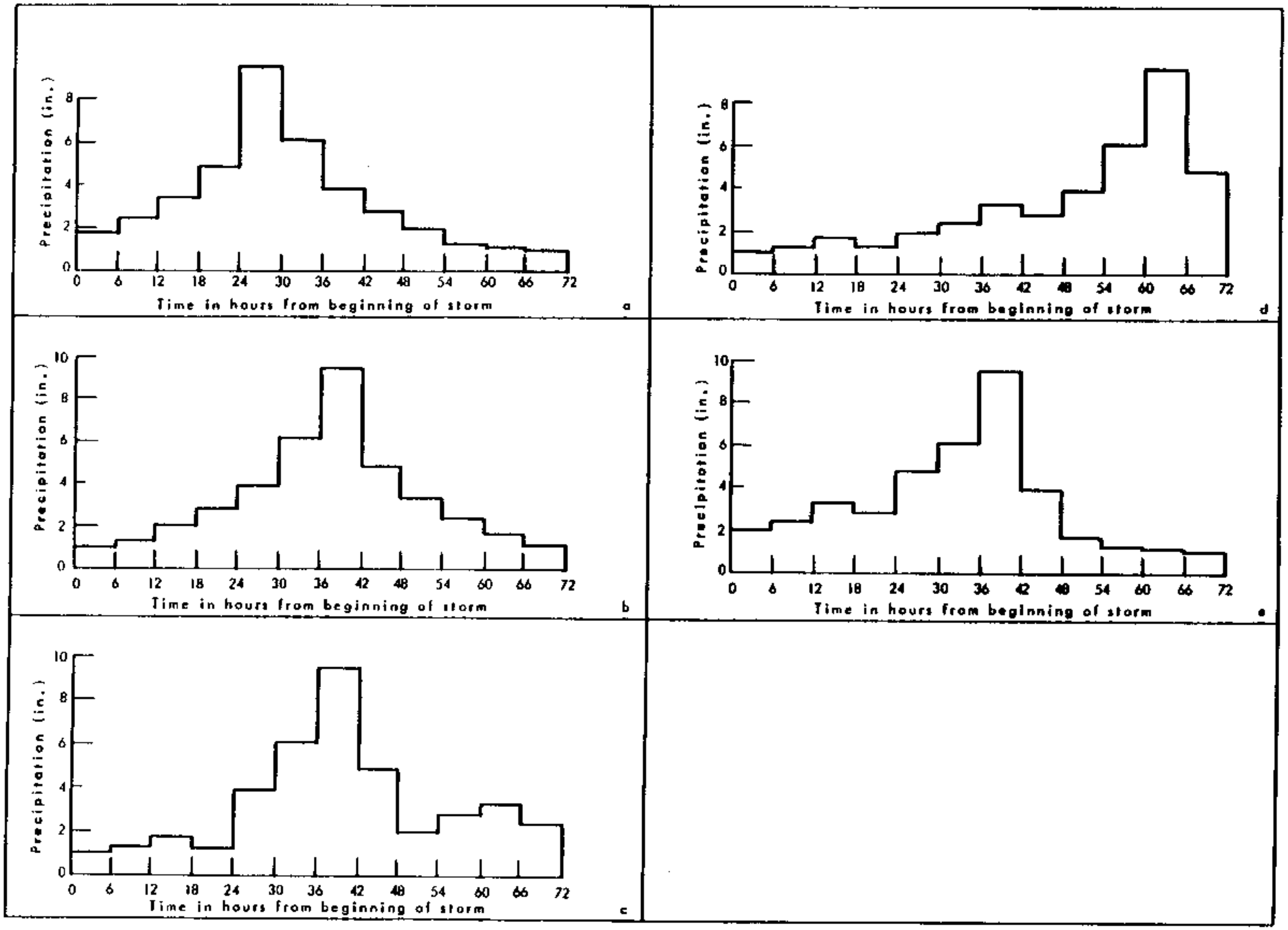

Figure 15.12.--Sample PMP time sequences (from HMR 43).

9. Areal distribution of general storm PMP

This study does not provide a specific procedure that enables the user to obtain the areal distribution of PMP for the general storm. The complexity of the orographic terrain makes the development of such a procedure extremely difficult, in comparison to that devised for the non-orographic United States east of the 105th meridian (Hansen et al., 1982). Nevertheless, as an interim measure in the interest of providing some guidance, it is recommended that an approximate distribution may be derived by developing an isopercental analysis based on the 100-year precipitation frequency maps from NOAA Atlas 2 (Miller et al., 1973). This approximation was used to develop the individual storm analyses for this study, and has been used on other occasions to represent storm distributions.

Another approximation may be used for those instances where a significant storm has been observed that has a sufficient number of observations to allow a storm pattern to be drawn over the specific basin of interest. If such a storm has been observed, then the storm pattern can be used to set an isopercental analysis for the PMP distribution. However, only a few such storms have occurred in the northwestern states that have sufficient observations to allow a meaningful isohyetal analysis to be drawn.

It is left to a future study to resolve the issue of how to distribute general storm PMP throughout a basin. Hopefully, as more information becomes available and with the use of geographical information systems (GIS), better understanding and insight into this problem will evolve.

10. Temperature and wind for snowmelt (from Chapter 8 of HMR 43)

If the contribution from snowmelt is of interest, the following guidance has been taken from HMR 43 (see Appendix 5 of this report for a worked example). Figure 15.13 shows the recommended 72-hour temperature sequences for the period before the PMP storm either west or east of the Cascades for selected seasonal periods. Dew points prior to the PMP storm are determined from the dew-point difference curves also shown in Figure 15.13, and are applicable to all months.

Figure 15.14 shows maximum January 6-hour winds west of the Cascade Divide. HMR 43 suggests that for sheltered drainages, a factor less than 0.75 be used; and for exposed locations at high elevations (above 3000 feet estimated), a factor greater than 0.75 is recommended. Seasonal variation of maximum winds is shown in Figure 15.15. To determine the durational variation of PMP winds by 6-hour increments, refer to Figure 15.16. East of

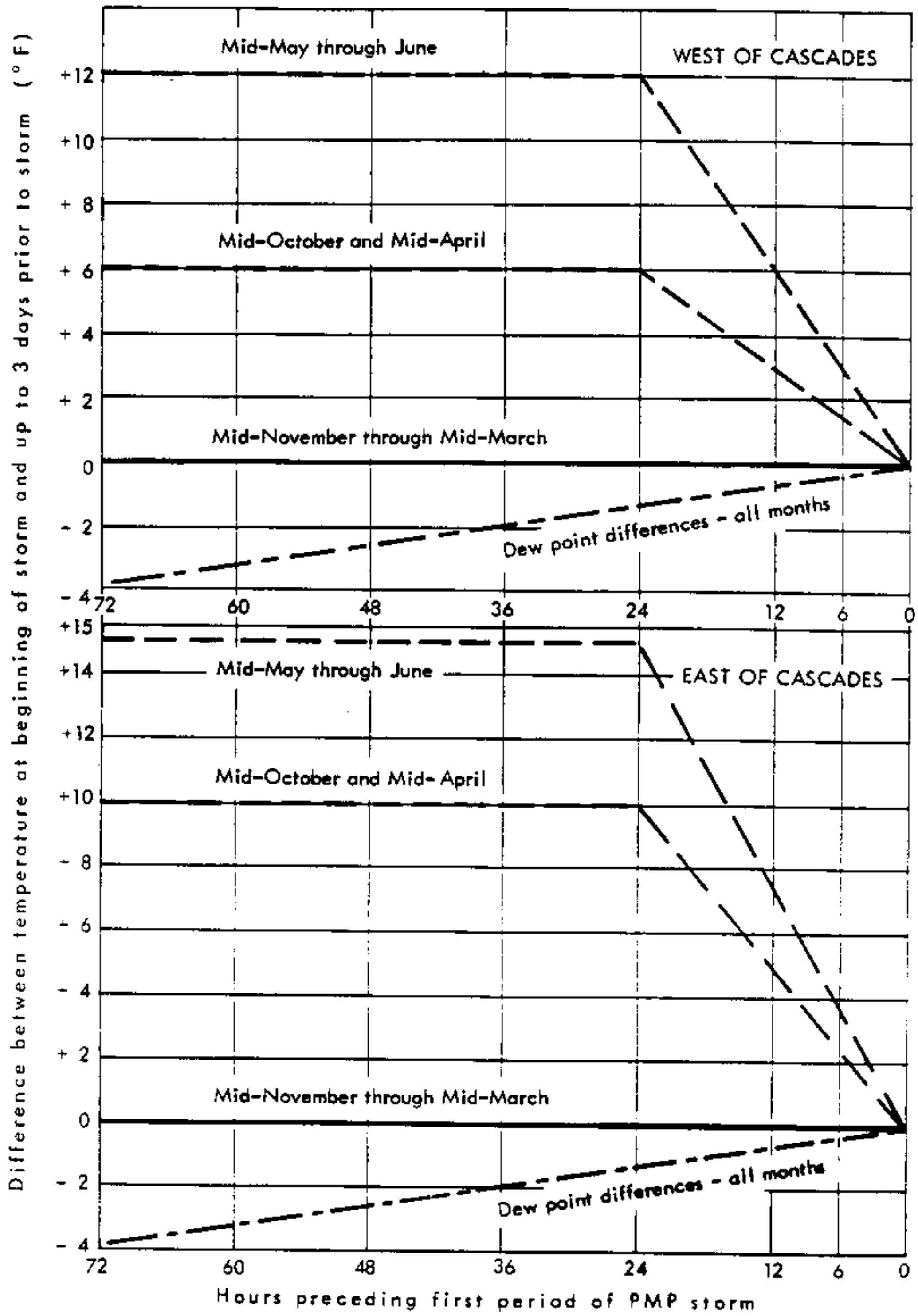

Figure 15.13.--Highest temperatures prior to PMP storm.

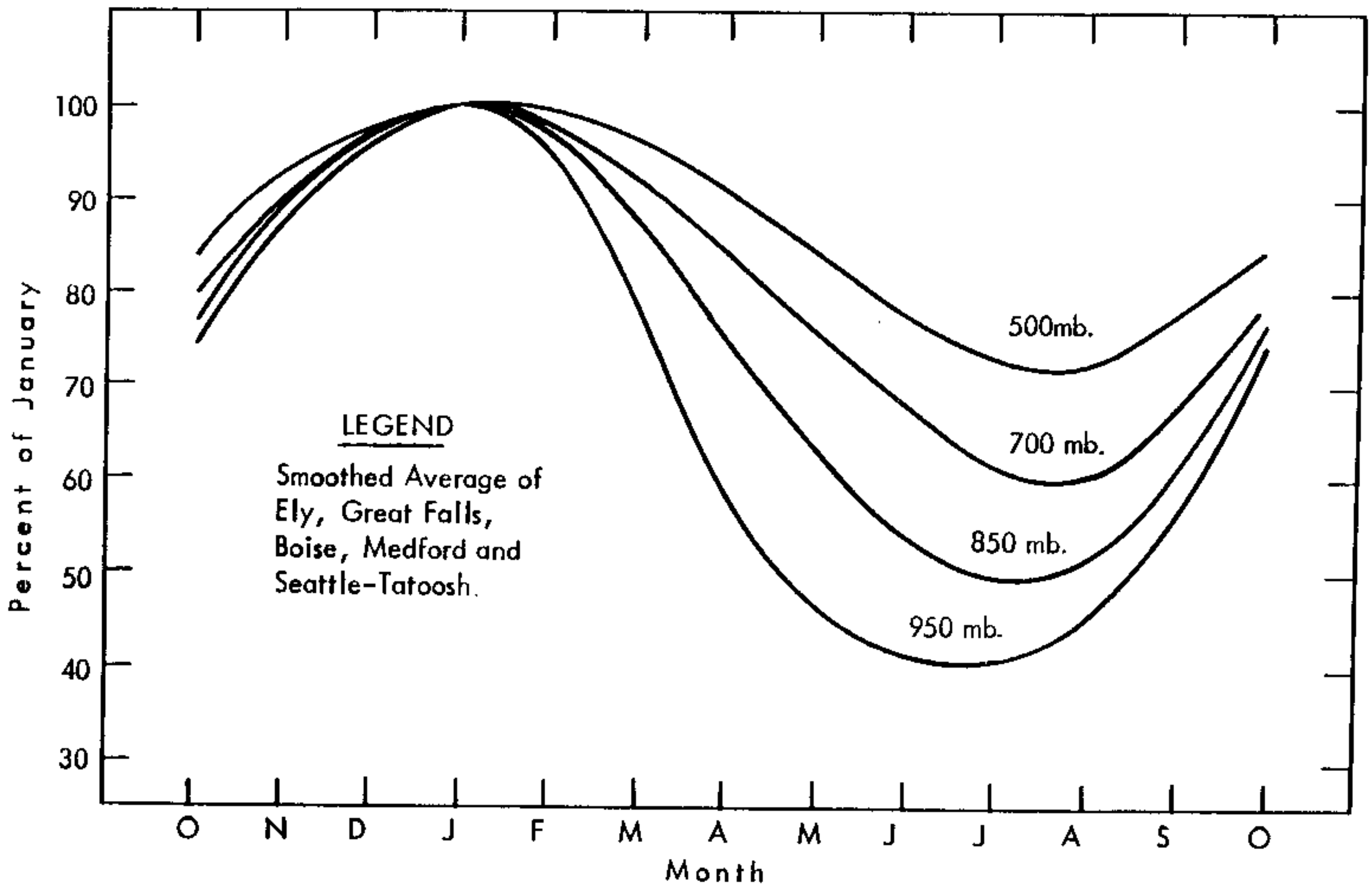

Figure 15.14.--Maximum winds west of the Cascade Divide (HMR 43).

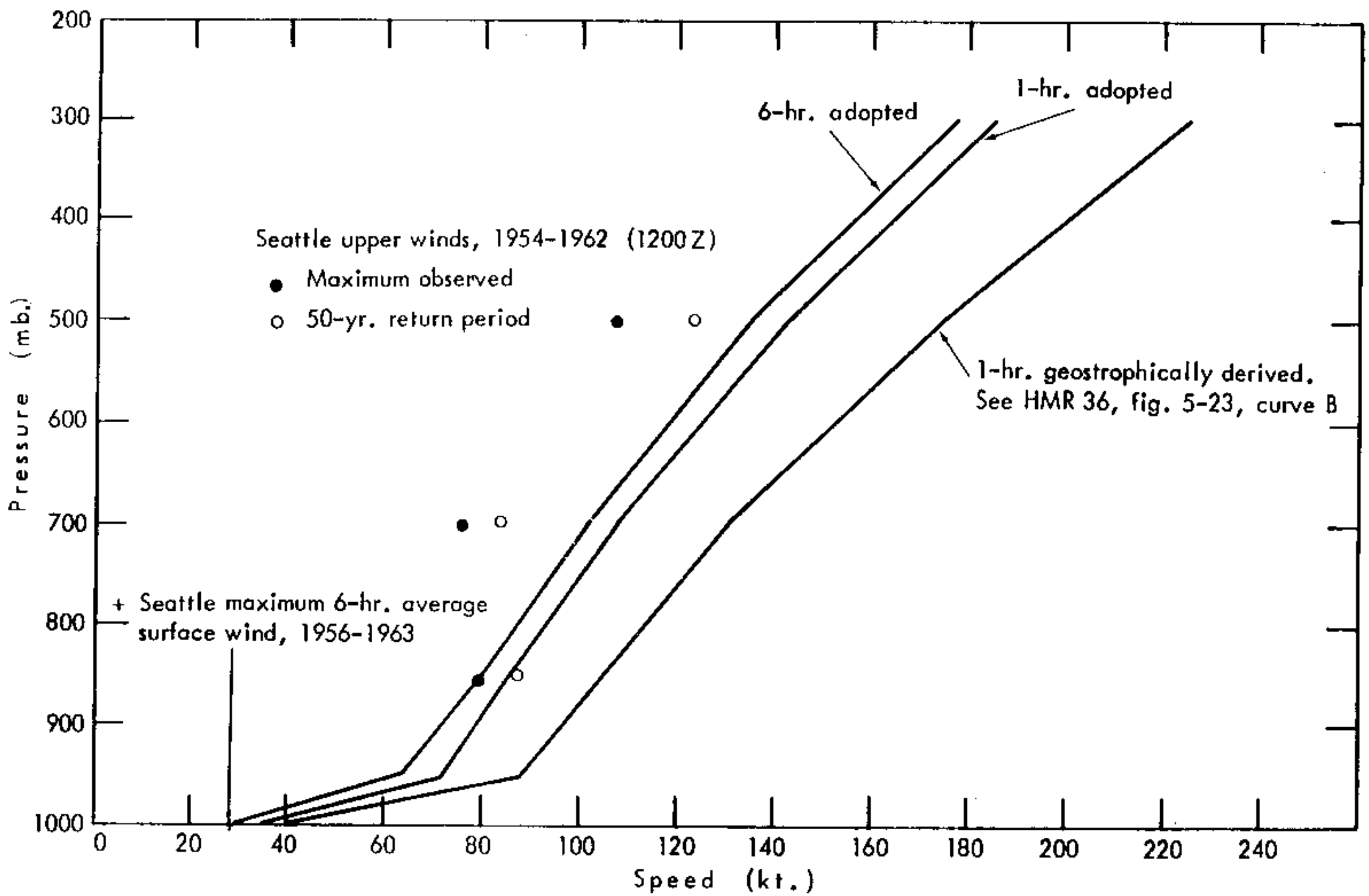

Figure 15.15.--Seasonal variation of maximum wind speed (HMR 43).

the Cascades, use Figures 15.15, 15.16, and 15.17 for these wind estimates. In Figure 15.17, a few selected locations are identified as guidance for elevation effects on winds east of the Cascades, as represented by the dashed curve.

The following steps are taken from HMR 43 (as given in Appendix 5 of this report) to obtain temperature, dew point, and wind sequences prior to and during a PMP storm.

A. Temperature and dew points during PMP storm

(1) Read the 12-hour, 1000-mb dew point (temperature) from Figures 15.18 to 15.29 for desired month at the basin location.

(2) Obtain the precipitable water (W_p) corresponding to this temperature from Figure 15.30. Enter this figure with the 12-hour temperature on the abscissa and read the corresponding W_p on the ordinate.

(3) Read the percentage ratios of W_p for each of the twelve 6-hour periods to W_p for the maximum 12-hour dew point from Figure 15.31.

(4) Multiply the 12-hour W_p by the percentages from step A (3). This gives W_p for each 6-hour increment during the PMP storm.

(5) Using the W_p values from step A (4), enter Figure 15.30 to obtain the corresponding 1000-mb temperatures for each duration for the required month.

(6) Adjust these temperatures to the elevation of the area of interest. This is accomplished by use of Figure 15.32. Starting with the 1000-mb temperature on the abscissa, proceed parallel to the sloping lines to the basin elevation and read the adjusted temperature on the abscissa.

(7) Rearrange temperatures in A (6) to conform to the adopted PMP storm sequence.